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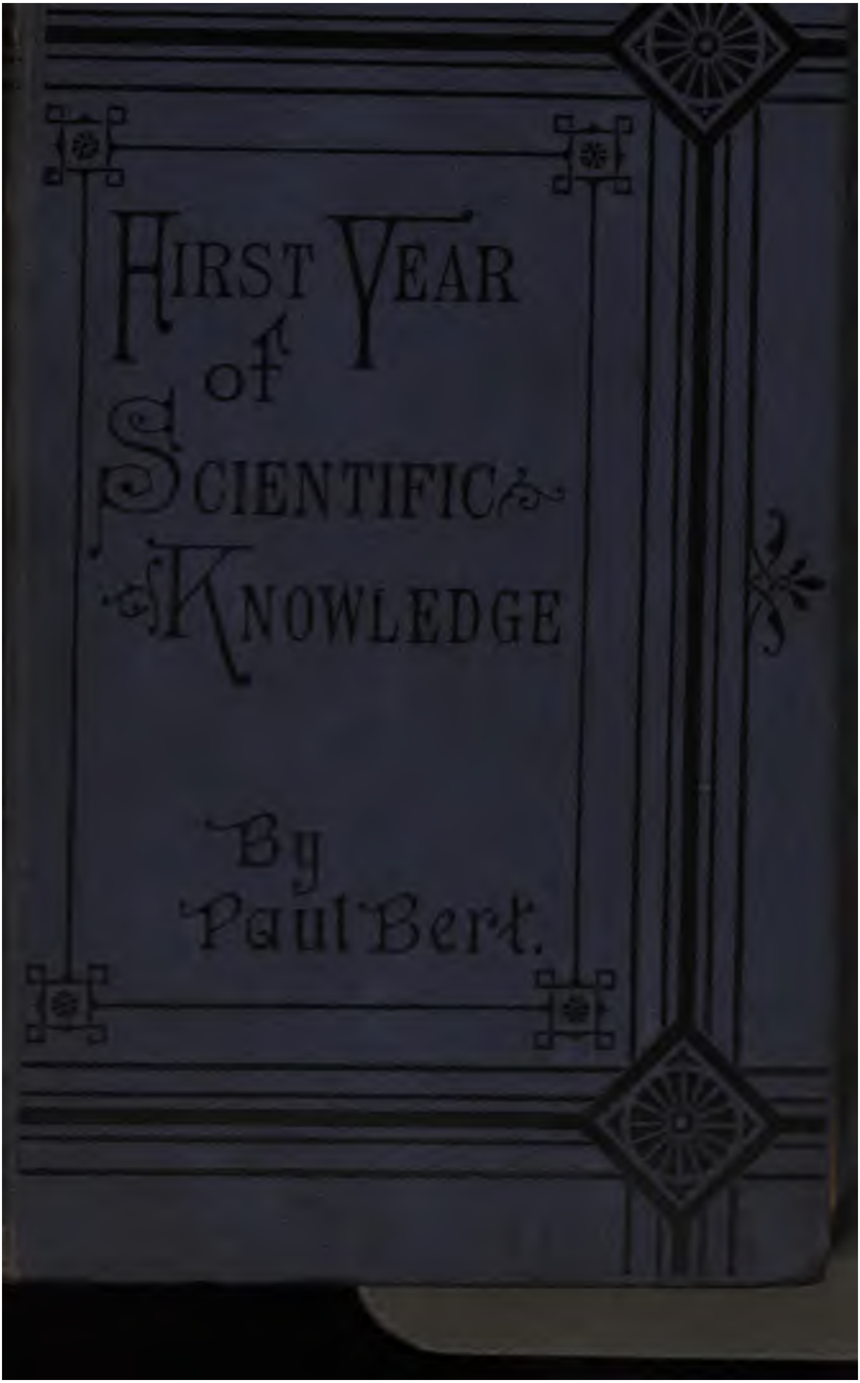

FIRST YEAR of SCIENTIFIC KNOWLEDGE

By
Paul Bert.

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OF

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BY

PAUL BERT

Member of the French Institute
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PREFACE

In issuing an English Edition of M. Paul Bert's famous Book, the Publishers would mention that its success has been so great in France that in 3 years 500,000 copies have been sold, and that there is scarcely a school, even in the smallest village, which does not use it.

The translation, which we owe to the pen of Madame Paul Bert (a Scotch Lady), has been modified so as to render it suitable to the requirements of English schools, but the general plan of the work has in no way been changed.

FIRST YEAR
OF SCIENTIFIC KNOWLEDGE

NATURAL HISTORY

I — ANIMALS

DIVISIONS OF THE ANIMAL KINGDOM

1. Classification. — The study we intend to pursue together on the present occasion is, as you know, *Natural History*, and we will begin with the most interesting part of this science, and that with which you are already best acquainted, namely, the natural history of **animals**.

Animals, I am well sure, interest you more than *plants*, and much more than *stones*. For *animals* grow, and move about; they feel, and manifest will; they live and they die. *Plants* also live and grow, and die; but they never move out of their place, and feel neither blows nor caresses. As for *stones*, they neither move about, nor do they die, and they remain for ever unchanged, if nothing comes about to displace or alter them.

You already knew all this, and you are moreover aware that *animals* are exceedingly varied in shape as well as in size. A whale, a fly, an elephant, a sparrow, a tiger, a snail, a cockchafer, a spider, an earth worm, are animals that widely differ from one another, and you have all certainly heard about them. Their history no doubt interests you, and you like to learn what services they may be able to yield us, or with what dangers they menace mankind.

This is not all, you are also aware that we ourselves in many respects resemble some animals, especially if we consider our internal construction. You know that you have a *heart* beating in your breast, that you have *lungs* with which you breathe, a *stomach* and *intestines* that digest, *eyes* that see, and *ears* that hear.

And if you have ever happened to look at a butcher's stall, or to have seen any one prepare a rabbit or a hare, you know that the ox, the sheep, the pig, the rabbit, and many other animals have an internal* organization more or less similar to our own. Thus in studying animals pretty closely we study our own selves, and you can all easily conceive how very interesting this must be.

But the first difficulty that presents itself is, to determine with which part of our wide and interesting subject we shall begin; and I have no doubt you would feel yourselves somewhat at a loss, were you left alone to decide this. I will give you my opinion. In the course of these last years, since you were quite little children, we have learnt together a great many things about animals; your reading books, story books and picture books have also given you instructive and attractive information on the same subject.

You all know, as well as I do, that the *lion* is a great African animal that kills and devours oxen and even men; that the *ostrich* is a large bird that lives also in the African desert, and you may have pretty correct notions about *sharks*, *rattle snakes*, *humming birds*, *crocodiles*, *camels*, and so on. Now that you have grown big, we must give up learning all these things at random, and arrange all our notions of animals in proper order, for this is the only way to retain what we learn, and to be able to profit by it. We will complete our knowledge as we go along.

For this purpose we must not study animals the one after the other, without method. We must follow out what naturalists* call a *classification*, and group together the animals that have the greatest resemblance to each other, so as to avoid having to repeat in reference to each of them that which they all have in common. Thus we will put all the *birds* side by side, and say once for all that they all have a beak, wings and feathers.

But it is no easy matter to make a good and rational classification. One must know exactly in what respects animals resemble each other, also what differences exist between them, and this demands attentive examination without and within.

2. Animals that have bones and animals that have no bones. — Can you tell me, George, what differences there are between a horse and a fly? I see the question makes you laugh. But that is not a sufficient answer; try and tell me. Well, Sir, a horse is a very big animal, and a fly is quite little. That's true; but here is a wood-cut which shows you a fly magnified, and another in which a horse is represented quite little. You would never take the one for the other, notwithstanding the size. Do you see nothing else?—A fly has *wings*, and a horse has none.—Ah! that is better: but suppose some accident had deprived the poor fly of its wings, would it then be quite like a horse? Of course not. What other difference could you find, Paul? A horse is covered with hair, and a fly has none. Are you sure of that? Catch a fly and look at it with this glass*. See, its body is covered with hairs. True they are very small, but yet they exist. James, I see you have something to say.—Sir, a fly has *six* legs, and a horse has but *four*. — Ah! that's a good observation, and will hereafter prove useful. But supposing the fly had lost, along with its wings, two of its legs, what then, can you find no other difference? No, say you. Ah! there are many nevertheless, and very great ones too.

Can we crush a fly? Oh! yes, very easily, and nothing remains but the external parts: the skin, the legs and the wings. Could we do the same with a horse? I know very well that we have not in ourselves sufficient strength. But suppose a house were to fall on it, would it thereby be crushed and reduced to a sort of pulp, as was the case with the fly? No, and why? *Because the horse has inside its body hard parts, bones that cannot be crushed, whilst the fly has none, not even very tiny ones.* **1.** The horse then is an **animal that has bones,** its body is supported by a **skeleton,** as we call the whole of the bony frame; the fly is an **animal that has no bones.**

Another difference of no less importance. **2.** Were a fly to be pricked, a drop of *colourless liquid* would come from the wound. But if a horse be pricked, what will flow from his wound? Ah! I see you all know that,

---

1. What fundamental difference is there between a horse and a fly? —

2. In what other respects do they differ?

blood! Yes, blood, a red liquid, very curious to examine, as we will do hereafter. **1.** So *animals that have bones have also real blood, red blood.* This is another important point.

3. Vertebrates. — Besides the horse, do you know any other animal having a skeleton and red blood? — **2.** Oh yes! Sir, the *cat*, the *dog*, the *pig*, the *ox*, the *rat*, the *hare*. You might add your own self to the list, don't you think so? — Oh! Sir. — Ah! you feel offended at being counted amongst animals. Yet it is quite correct to do so: we eat, we breathe, we are born, we die in the same way as animals do, and we are fashioned just like animals with blood and bones. This in no wise diminishes our moral superiority however; for though we live and breathe no better than animals, we think infinitely more and better than they. So there is nothing shocking or offensive in the fact, on the contrary.

But let us return to our subject. I must say, you have displayed but little imagination in searching out your examples. All the animals you have mentioned are very like each other, for they are all fourfooted, and are clad in hair, or fur. They are *hair* or *fur clad quadrupeds* *. Do you remember any others that have blood and bones? — Yes, Sir, the *birds*. — Very well; any others? — *Fishes*. — Any others still? — Serpents, frogs, lizards. — Quite right! and what general name is given to these three last? *Reptiles*. That's right. We will come back to this in a little while.

3. So, **Quadrupeds** B (fig. 1), **Birds** C, **Reptiles** D, **Fishes** E, *may be classed together as having bones and red blood.* **4.** They all come under the general name of **Vertebrata**, because among the bones of the body a certain number, called *vertebræ*, form the spine or backbone, from F to G, hence the name of *vertebral* or *spinal column* given to the whole series of those vertebræ. You may easily feel them under the skin, all along the back. **5.** Some vertebrates have no *limbs*, like

---

1. In what animals do we find red blood? — 2. Name some animals ormed with bones and having red blood, and in some respects resembling a horse. — 3. Name some other *animals quite* different from the horse, but that resemble each other in having bones and blood. — 4. Under what common name are all these animals ranked? — Why? — 5. What peculiarities does the skeleton of the serpent present?

serpents D, the vertebral or spinal column, together with the head (or properly speaking with the *skull*, a name given to the bones of the head taken as a whole),

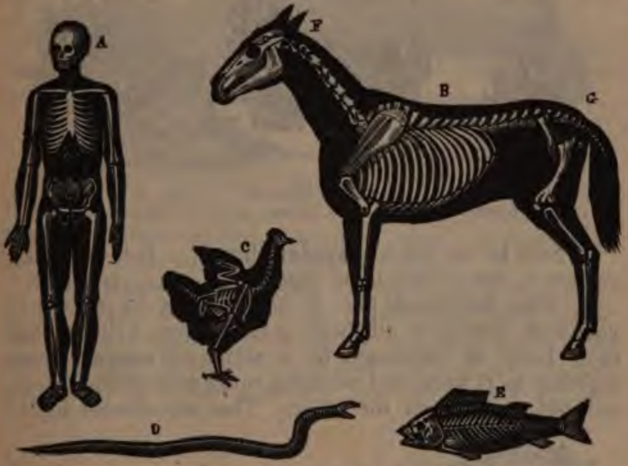

Fig. 1. — *Vertebrate* animals, that is to say, animals that have a spine or backbone FG called *vertebrates*. — A, man; B, quadruped; C, bird; D, reptile; E, fish.

form, in their case, all the skeleton; but almost all vertebrates have limbs. We will continue this part of our study afterwards.

4. **Annulata.** — **1.** We will now pass on to those animals that have *neither bones nor red blood*, and are called *invertebrates*, to distinguish them from the others.

2. We have already spoken about the *fly* that has two wings and six feet. Do you know any other creature you might class along with it. Shall we say a *cockchafer* (fig. 2)? Yes: evidently. How many wings has a cockchafer? — *Four*. — How many feet? — *Six*. Quite so. — Mention another. — A *butterfly* (fig. 3). — It has also four wings and *six* feet. — *A dragonfly* (fig. 4) has also four wings and *six* feet. — Quite

---

1. What name is given to animals that have neither bones nor red blood? — Why? — 2. Name some animals with six feet.

right. That's enough in the mean time. **1.** *All those six footed creatures are called* **Insects.**

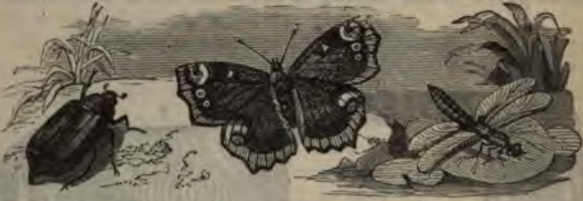

Fig. 2. — Cockchafer (insect), 6 feet. Fig. 3. — Butterfly (insect), 6 feet. Fig. 4. — Dragonfly (insect), 6 feet.

2. Now let us catch a **spider** (fig. 5). It is very like an insect, but it runs upon *eight* feet.

3. This **milleped** (fig. 6) has at least 20 pairs. If you look closely at all these animals, you will see that their body is composed of a series of **rings** strung together as it were, and working upon one another, *articulated* the one on the other. That *woodlouse* (fig. 7) I see running in yon corner is also composed of a succession of rings.

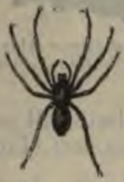

Fig. 5. — Spider, 8 feet.

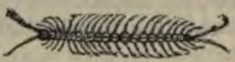

Fig. 6. — Milleped, 20 pairs of feet.

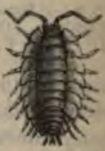

Fig. 7. — Woodlouse (crustacean).

4. The *crayfish* (fig. 8), also, belongs to this group, only the rings that form its body are hard and crusty. It is therefore called a **crustacean** (from the Latin *crusta*, a crust).

Here now is an *earthworm* (fig. 9), and here a *leech* (fig. 10). They also have rings; only the head is not distinct from the body, neither have they feet; their skin is not coriaceous like that of insects, nor stony and hard

---

1. What general name is given to animals with six feet? — **2.** What *insect like animals* have eight feet? — **3.** To what group do the milleped and woodlouse belong? — **4.** The crayfish?

like that of a crayfish. **1**. They come under the general name of *worms*.

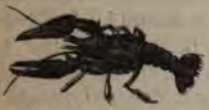

Fig. 8. — Fresh water cray-fish (crustacean).

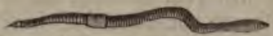

Fig. 9. — Earth-worm (worm).

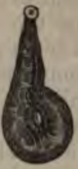

Fig. 10. Leech (worm).

2. *Insects*, *Spiders*, *Millepeds*, *Crustaceans* and *Worms* are often designated by the general name of **annulata** (from the Latin *annulus*, ring), because their bodies all seem to be composed of *rings*.

5. Molluscan. — Look at this *slug* (fig. 11); it is quite naked, soft and pulpy; and again this *snail* (fig. 12), quite as naked and pulpy, although it has been clever enough to make for itself a *shell* that protects it, and wherein it finds house shelter; see this *mussel* (fig. 13),

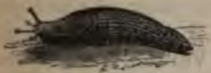

Fig. 11. — Slug (mollusc).

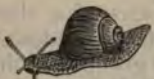

Fig. 12. — Snail (mollusc).

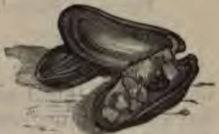

Fig. 13. — Mussel (mollusc).

whose body is sheltered between two shells. **3**. *In these animals no traces of ring shaped divisions are to be found : therefore they are not annulates. They have neither bones nor red blood*: so they cannot be* vertebrates.* **4**. The name given to them is **Mollusca**.

6. Radiates. — Lastly here are two illustrations. The one represents an animal very common on the sea shore, and which bears the characteristic name of *star-fish* (fig. 14). The other (fig. 15) is a magnified representation of a tiny creature that lives in colonies* formed by countless numbers of little beings similar to the one

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1. To what group do the earth-worm and the leech belong? — 2. Enumerate these different groups; what common name is sometimes given to them. — 3. What are the characteristics that distinguish snails, etc. from annulates and vertebrates? — 4. By what name are they designated?

figured here; those minute animals, called *polypi*, deposit around themselves a sort of slimy stony sheath, and the reunion of all those sheaths constitutes what is called a *polypier;* these polypi often acquire great dimensions, and form rocks, reefs* and even islands. **1.** These animals, although, as we shall see later, belonging to two widely different groups, differ from all those which we have hitherto considered in having a *central mouth ;* **2.** as the body is produced into a series of rays which surround this, the term *Radiates* is often applied to these similarly-constructed animals.

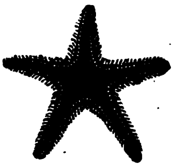

Fig. 14. — Star-fish.

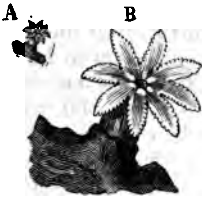

Fig. 15. — Polype. — A, actual size B, magnified.

This is then the basis of a classification of what has been called the *Animal Kingdom.* **3.** There are, as we have seen, four great groups : 1. the **Vertebrates**, 2. the **Annulates**, 3. the **Molluscan**, 4. the **Radiates.** The best thing we can now do is to study these different groups, each in its turn, considering briefly the principal animals comprised therein.

SUMMARY. — DIVISIONS OF THE ANIMAL KINGDOM.

1. Generalities (p. 7). — An *animal* grows, moves about, feels, lives and dies.

2. A *plant* grows, lives and dies, but does not move out of its place, and shews no sign of feeling.

3. A *mineral* remains unchanged unless displaced, broken, or altered by some outward cause.

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1. What is the resemblance between a sea-star and a polype? — 2. What *name is given to these* animals? — 3. What are the four great groups of the animal kingdom?

4. **The animal kingdom** comprises 4 great groups, **Vertebrates, Annulates, Molluscans, Radiates.**

5. **Vertebrates** (p. 10). — By this name are designated all animals having *bones*, or what is called *a skeleton :* a horse is a *vertebrate.*

6. The name of *vertebrate* is based upon the fact that amongst the bones of these animals those that form the spinal column are called *vertebræ.*

7. The vertebrates are the *only* animals that have **red blood.**

8. **Annulates** (p. 12). — The *annulates* (insects, spiders, millepeds, crustaceans, worms) are animals that have neither *bones*, nor *red blood*, and whose bodies are formed by a series of **rings** juxtaposed, and that play on one another. A *woodlouse* is an *annulate.*

9. **Molluscans** (p. 13). — The *Mollusca* have neither *bones*, *red blood*, *nor rings.* Their body is **soft** and **pulpy**, sometimes hidden in a shell. A *snail* is a *Molluscan.*

10. **Radiates.** — Certain animals are possessed of a mouth which, unlike our own, is centrally placed. When the body is produced at the sides of this into a series of rays, such animals are often called *Radiates.* The starfish or sea-star is a Radiate, as is also the Sea-Anemone.

I — VERTEBRATES

1. *The* **Vertebrates**, as we have already said, *are animals that have* **bones** *and* **red blood.** 2. We also know that they are divided into several great categories: *Mammalia, — Birds, — Reptiles, Amphibians,* and *Fishes.*

7. **Mammalia.** — 3. There are, in the first place, *Quadrupeds** covered with hair or fur. 4. As they nourish their young with milk, the name of **Mammalia** (fig. 16) has been given to them, *mamma* being the Latin name of the udder or *organ that gives milk.*

8. **Birds.** — Tell me what characterises **Birds** (fig. 17), what do they all possess? — 5. You told us that,

---

1. What are the general characteristics of the Vertebrates? — 2. Into how many categories are they divided and what are they? — 3. Which group ranks first among the Vertebrates? — 4. Why is the name Mammalia given to them? — 5. What characterises the bird group?

the water so as to be able to breathe air, it would be drowned. Some men are able to remain with their heads under water for two minutes without being asphyxiated, that is to say, suffocated; as for the frog, it can remain much longer, but not above an hour, excepting during the cold winter season, when the frogs become torpid, and seem quite dead. So you see the frog is an *aërial* animal, like the lizard and the serpent. The frog, however, has not been thus all its life. **1**. When young it was a *tadpole*, you all know that; it *then lived continually in the water*, and was an *aquatic* animal. **2**. So here is an animal which when quite young was *aquatic*, and that has become *aërial* after having undergone what is called its metamorphosis or transformation. For it and its allies, toad, salamander, newts **3**. a group has been formed, called the **Amphibians***, which signifies *double life.*

Still another difference exists between Amphibians and Reptiles. Examine the skin of the frog, *it is moist and* nearly *smooth;* now look at that of the snake: is it so also, George? — No, Sir, it is quite *covered over with scales.* — Like that of a fish? — Yes, Sir. — Look again, you have made a mistake. See, the scales of the goldfish are quite distinct and separate, so that were it handled too roughly, one or more might be wrenched out just as a hair might be pulled from your head or a feather from a bird. This is quite impossible with the scales of the snake; what you take for scales are merely folds *of the skin* : they are called *false scales.*

Let us now recapitulate. **4. Reptiles** are *aërial* animals; their skin is covered with false scales. — **5. Amphibians** are *aquatic* animals in their youth, and *aërial* when fully developed; their skin is bare. — **6. Fishes** are *aquatic* animals; their skin is covered with real scales, distinct the one from the other.

---

1. What was its mode of existence when it was a tadpole? — **2**. What deduction do you draw from this fact? — **3**. What group has been formed for animals of the same kind as the frog? — **4**. What are the characteristics of reptiles? — **5**. What are those of the Amphibians? — **6**. What are those of fish?

SUMMARY. — VERTEBRATES.

1. **Division of Vertebrates** (p. 13). — **Vertebrates** are divided into several important categories, namely *Mammalia, Birds, Reptiles, Amphibians* and *Fishes.*

2. **Warm-blooded animals** (p. 16). — The **mammalia** are hair clad, and give milk to their young.

3. **Birds** have a bill or beak, wings, feathers and two feet.

4. Mammalia and Birds have *warm blood.*

5. **Cold-blooded animals** (p. 16). — **Reptiles** have *cold blood*, their skin is covered with false scales.

6. **Amphibians** have cold blood, their skin is bare. When young they live in water and are *aquatic*. When full grown they breathe air, and are obliged to come to the surface for this reason : they are then aërial animals.

7. From this double life they take their name of *Amphibians*. a word signifying *two lives*.

8. **Fishes** have cold blood, are *aquatic*. Their skin is covered with *real scales*, distinct from one another.

[Easy subjects for composition may be found at page 81.]

VERTEBRATES. — 1 Mammalia.

11. Mankind. — We will begin the study of Mammalia with *mankind;* for man belongs to that category.

I willingly allow that man would have well merited a particular division, all for himself, so great is his superiority over all the other members of the group. But let us for a moment forget our intellectual faculties, and consider only our body : in this case we cannot but confess that we have no little resemblance to monkeys.

We walk upright, however, and stand erect on our two legs, and that monkeys cannot do; we have strong and yet delicate hands, with which, on account of the existence and position of the thumb, we can grasp firmly or feel nicely. Our body is almost bare, excepting the head and part of the face.

All the members of the human family who live dispersed over the surface of the globe are not exactly similar to the men of this country. Even here in our village there are fair people and dark people, pretty different from each other. A big fair-haired native of Denmark* for instance, and a little dark Italian resemble each other still less. But all the populations of *Europe* have a **whitish** skin, as we have (fig. 21), regular features, a straight nose, well poised jaws, and smooth but silky and sometimes wavy hair. *Chinese* (fig. 22) have **yellowish** skin; their hair is smooth, black and rough; their eyes are obliquely set, their teeth prominent. *Negroes* (fig. 23) have **black** skin, frizzled woolly hair, very *prominent* jaws and a broad flattened-out nose; they

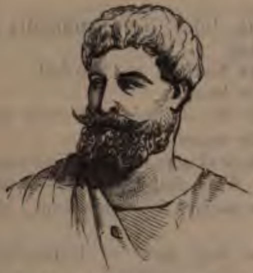

Fig. 21. — White race (Europe).

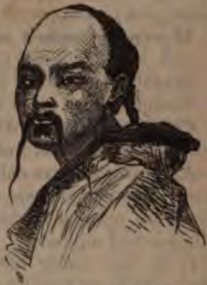

Fig. 22. — Yellow race (Asia).

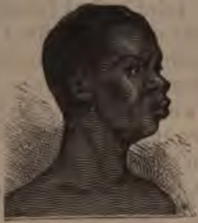

Fig. 23. — Negro race (Africa).

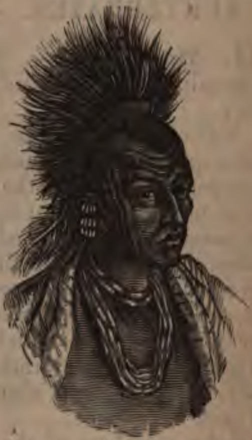

Fig. 24. — Red race (America).

are less intelligent than the Chinese, and much less so than white men. In *America* (fig. 24), there exists another race, which somewhat resembles the yellow race, only the men are taller and stronger, and their skin has a **reddish** tint. There are also many other races of less numerical importance or less easily defined. **1.** We will for the time being take notice only of the *white* race of Europe, the *yellow* race of Asia, the *black* race of Africa, and the *red* race of America. Only you must know that white men being more intelligent, more industrious and more courageous than the others, have spread over the whole world, so that the inferior races disappear as they are subjugated* by them.

Moreover, the inferiority of some races of the human family is most manifest. For instance Australia* is peopled by men of stunted stature, with blackish skin, straight black hair, and very small heads. They live in groups, and neither cultivate the ground nor possess domestic animals (excepting a sort of dog). Their intelligence is very limited. In other parts of the world some tribes exist that do not even know how to make fire.

12. Monkeys. — In the highest rank amongst *monkeys* or apes we must place three great species much more intelligent than the others, and having closer resemblances to the human family.

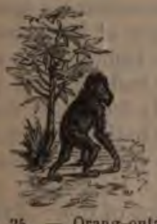

Fig. 25. — Orang-outang (Borneo).

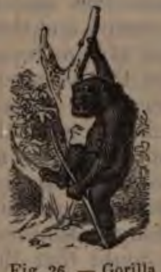

Fig. 26. — Gorilla (Africa).

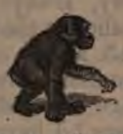

Fig. 27. — Chimpanzee (Africa).

2. The most anciently known of these large monkeys

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1. What are the principal races amongst men? — 2. Name the three highest genera of monkeys.

is the *Orang-outang* (fig. 25), which lives in the forests of Borneo*, and whose stature sometimes reaches the height of more than 4 feet. On the Gaboon* coast and in Guinea* the enormous *Gorilla* (fig. 26) is to be found. This powerful animal has been known to attain the stature of 6 feet. The *Chimpanzee* (fig. 27) also is an inhabitant of these same countries; its height rarely goes beyond 4 feet.

These animals have no tail, they walk generally with the help of both feet and hands, putting only however the knuckles of these last to the ground; sometimes they even stand almost erect like a man. But like all other monkeys, their great toe is like a real thumb, separated from the other toes as our thumb is from our fingers; this enables them to climb with the greatest ease; they are able to seize the branches of trees with their feet as well as with their hands. **1.** This is the reason why you will often find that monkeys are designated by the name of *quadrumana* (four handed), whilst the name of *bimana* (two handed) is applied to man.

These great monkeys live in little families, are extremely intelligent, of course I mean for animals, are easily tamed* when caught young, and can be sometimes trained to make themselves useful in household service on account of their stature and their almost erect gait.

The other species of monkeys are extremely numerous. They live in the warm climates of both hemispheres*, almost always in countless troops, gay and noisy, always climbing, gamboling and teasing one another in the forests, where they mainly feed upon fruit.

13. Bats. — We shall now pass on to the *Bats*. I am sure that at first thought, it astonishes you that I should range the Bats amongst *Mammalia*. Have they not wings? I have no doubt that the fact of their flying would rather induce you to consider them as *birds*.

In order to give you proofs against such an error, I caught one last night, by means of a light, and put it in the schoolroom, leaving the window open. Here it is quite unharmed under this glass shade. Let us set to work and examine it (fig. 28).

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1. What name is often given to monkeys?

1. In the first place, we see that its *body is covered* not with feathers, but with *hair*; moreover, its head is adorned with a pair of *long ears*, and certainly you never saw a bird have ears. To enable us to examine it more closely I will take it out of its prison; only, for that purpose, I will prudently, but without hurting it, make use of a pair of pincers. Why so? Because it has got very *sharp teeth*, and would be very ready to use them on my hands. You never heard of a bird having teeth, did you? Thus the bat has neither a beak nor feathers, whilst it is provided with teeth, long ears and fur; it cannot then be a bird.

Fig. 28. — Bats (Mammalia). — The bat has neither beak nor feathers: but has hair, ears and teeth. Its wings are composed of the skin of the back and breast stretched out, and sustained by the prolongation of the finger bones. — Nocturnal animals useful to agriculture.

And its wings? Ah! they also demand close examination. See I have spread one out completely. How different it is from a bird's wing. **2**. It bears no feathers whatever; it is composed of a *thin membrane** or film stretched out upon a bony frame, and unfolding like a fan. The bones are in reality those of the fingers considerably lengthened out. The membrane is double, and is formed by a prolongation of the *skin of the back and that of the breast*, which has become in that particular place very thin. This membrane extends from the arm to the tail, embracing this and the leg. This is certainly a very odd kind of wing.

Now, in order to see how our bat can use these strange wings we will let it free. See, it flies away clumsily and heavily, and seems not to know where to direct its flight. Can you tell me why? **3**. Of course you can. It is because the sun is bright, and the poor bat that shuns light and never comes out of its corner until twilight*, being what is called a *nocturnal** animal, is altogether dazzled. Ah! it has found the open window, and will now be able to go and hide itself in

---

1. Why cannot bats be ranked amongst birds? — 2. What is the difference between a bat's wing and a bird's wing? — 3. What name is given to animals, that like the bat avoid the light of day?

some dark hole or cellar. There, with its wings folded, it will suspend itself by its hind claws, and will sleep head downwards all day long. 1. In the evening it will wake up again, and go forth to hunt insects, amongst which it makes great havoc. 2. So you see *the poor little creature is a friend to gardeners and farmers, and deserves to be protected.* Some foreign bats are fruit-eaters.

3. During winter, bats remain in their holes, where they sleep all through the cold season, and need neither food nor drink. They are then in what is called a *dormant* or *hibernating state**.

14. Insectivorous animals. — 4. Other mammalia, wingless this time, *live upon insects,* hence the name of *Insectivora,* insect eaters, sometimes given to them. 5. They are all of small dimensions: you can easily fancy that such food would scarce be sufficient to keep alive large animals.

6. In this country we have the *Hedgehog* (fig. 29), whose hair forms great spines which serve it as defensive weapons when it rolls itself up in a ball; it is also an animal that sleeps during winter, a hibernating animal.

Fig. 29. — Hedge-hog. — Instead of hair it has spines. And sleeps through the winter.

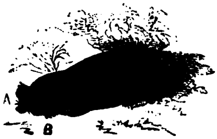

Fig. 30. — The mole. — It eats white worms or larvae (must not be destroyed).

The *mole* (fig.30), that with its strong broad feet hollows out subterraneous galleries, is another example; it has extremely small eyes, which like the openings of its ears are hidden in its soft silky fur. 7. *It is a great mistake*

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1. What is the principal food of bats? — 2. What must we conclude from this? — 3. Tell me why bats are said in winter to be in a dormant *state.* — 4. What is meant by the word insectivorous? — 5. What is in general the size of insectivorous animals? — 6. Name some of these animals. — 7. Why should the mole not be destroyed?

to destroy the mole, as people often do; it never eats the roots of plants, but swallows countless numbers of destructive *larvae** and *worms* that live deep down in the earth.

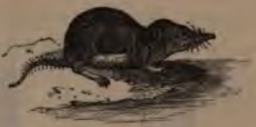

Fig. 31. — The shrew mouse. Feeds on insects.

The *Shrew Mouse* (fig. 31), another insect eater of our country, is very like the common mouse, only its nose is longer and sharper, and its well-whetted teeth are perfectly adapted to its mode of life, enabling the little creature to break open the thick and crusty carapace* of insects.

15. Carnivorous animals. **1.** We will now begin to study animals that live upon flesh, that devour mammals and birds alive. Those are the *Ferine* or *carnivorous animals* (from the Latin *caro, carnis*, flesh, and *vorare*, to devour).

The most perfect and complete type of the race, the best organised for the chase, is the **Cat**. Let us then examine our good **pussy**, if she will kindly allow us to do so. Look at her paw, in the first place, see how it is armed with sharp cutting claws; she well knows their value and takes good care of them, for when not required, they are withdrawn into the paw (fig. 32) so that their points do not even touch the ground, this keeps them always in good working order. The sharp point of the claw never comes out (fig. 33) of its sheath excepting when the animal stretches out its toes to climb or to strike its prey*. Look at its mouth (fig. 34); see on either side these long, strong and pointed teeth that lay hold of the prey*; behind them those others, sharp and cutting, that play upon each other like the blades of a pair of scissors, tearing up the flesh. What weapons these are! If a common cat can use them so as to do great harm, just think how a lion or a tiger might employ them. **2.** *For the tiger and the lion are merely enormous cats*, able to treat a man as a cat does a mouse.

The most formidable and fierce of the tribe, the

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1. What name is given to flesh-eating animals? — 2. To what well known class of animals do the lion and tiger belong?

Tiger (fig. 35), with its beautifully striped skin, is a native of Asia. It is exceedingly bold and daring, and attacks man with such ferocity that in 1875, in British India alone, 917 men fell a prey to them.

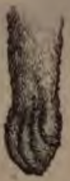

Fig. 32. — Cat's paw in repose. The sharp claws do not touch the ground.

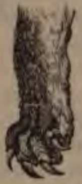

Fig. 33. — Cat's paw just going to strike its prey. The claws are stretched out.

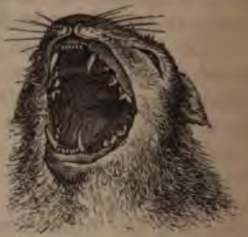

Fig. 34. — Cat's mouth. 4 long pointed teeth in front; sharp back teeth.

The *Lion* (fig. 36), an inhabitant of Africa and of certain regions of Asia, is less aggressive*; but it preys heavily upon wild and domestic animals. It has been calculated that each lion in Algeria* costs the colony* about £ 800 yearly.

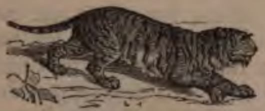

Fig. 35. — Tiger (Asia).

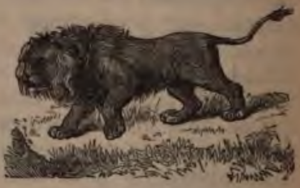

Fig. 36. — Lion (Africa).

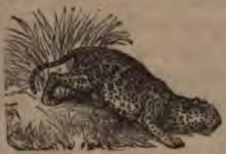

Fig. 37. — Panther (Africa and Asia).

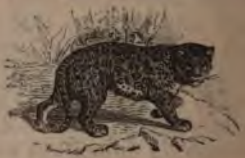

Fig. 38. — Jaguar (South America).

The beautifully spotted *Panthers* (fig. 37) but rarely attack man. Several species of its kind are to be met with in Africa and in Asia.

In South America, lives the *Jaguar* (fig. 38), almost as big as the tiger, but not nearly so dangerous for mankind: its skin is covered with spots. The *Puma* (fig. 39), whose skin is neither spotted nor striped, bears also the name of *American lion*, which name it justifies neither by its strength nor by its courage.

Fig. 39. — Puma (South America).

Fig. 40. — Lynx (Europe).

In Europe, we possess, of the cat kind, only the *wild cat* of our forests, the ancestor of our common domestic cat, and the *Lynx* (fig. 40), which is still found on some high mountains.

Next to the *Cats* come the **Dogs**. Their teeth somewhat resemble those of cats; but their claws are fixed, and cannot be withdrawn like those of pussy. We have in Europe the *Wolves* (fig. 41), which, though no very dangerous in the western parts of our continent, are very redoubtable in Asia and in the east of Europe, where they live in great bands; in Russia they devour, on an average, upwards of two millions sterling of cattle yearly. We have also the *Fox* (fig. 42), sly and clever hunter, that hollows out a home to dwell in.

Fig. 41. — Wolves attacking an elk (Europe and Asia). Very destructive to sheep.

Fig. 42. — The Fox Clever hunter o poultry.

In Algeria and in other parts of Africa, also on all the Asiatic shores of the Mediterranean sea and even in Greece, lives a sort of little wolf, the *Jackal* (fig. 43), that makes great havoc amongst fowls and game.

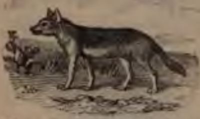
Fig. 43. — Jackal (Africa). Destructive to game and poultry.

The *Hyenas* (fig. 44) are African animals, they are big and strong, but prefer dead bodies to live flesh. They never attack man. The *striped Hyena* is a native of Algeria.

Bears are to be found all over the world, except in Africa. In Europe we have the *Brown Bear* (fig. 45); it lives in the Alps*, in the Pyrenees*, etc.; it is not much to be dreaded by man, being of a peaceful disposition, for it prefers, like many of its relatives, fruit and honey to the flesh of flocks and herds. The *white Bear* (fig. 46) which is to be met with in Spitzbergen*, in Greenland*, and in all icy regions of the north, with its neighbour the *Grizzly Bear* (fig. 47), are not of such an accommodating nature; they consider man as the most desirable prey, and it is often extremely difficult to get out of their reach.

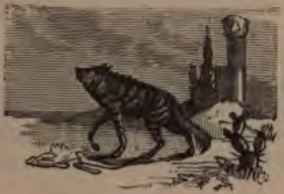
Fig. 44 — Hyena (Africa). Never attacks man.

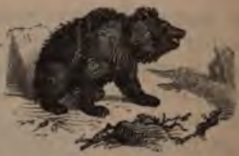
Fig. 45. — Brown Bear of the Pyrenees. Prefers fruits and honey, to flocks and herds.

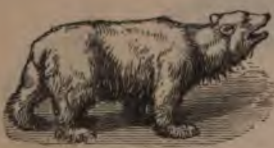
Fig. 46. — White Bear (icy regions). Height 47 inches.

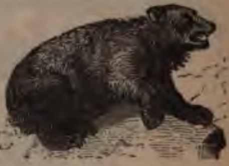
Fig. 47. — The Grizzly Bear (North America).

The *Badger*, a native of our forests (fig. 48), has some points of resemblance with the bear; it is exceedingly fond of fruit, but by no means disdains to pay a visit to the poultry yard.

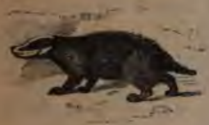

Fig. 48. — The Badger.
Eats grapes and poultry.

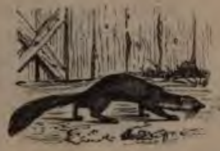

Fig. 49. — The Civet.

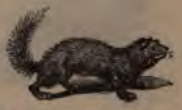

Fig. 50.—The Martin.
Live on poultry and small game.

Great enemies of fowls and small game are the *Civet* (fig. 49), the *Martin* (fig. 50), the *Weasel*, the *Ermine* (fig. 51) and the *Pole cat* (fig. 52) all of which are long slender creatures, common in European woods and hedges.

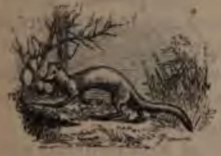

Fig. 51. — Ermine.

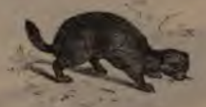

Fig. 52. — Pole Cat.
Eat poultry and small game.

In return, we search them out, not only to punish their depredations but also because their skin affords warm and beautiful *fur*. These furs are however much finer and thicker in cold countries. In Siberia* millions of skins are sold yearly, and it is the martins, ermines and sables that furnish the greater part of this costly merchandise.

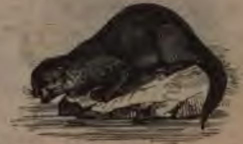

Fig. 53. — The Otter. Destroys fish.

The *Otter* (fig. 53), long bodied, pursues and destroys the fishes in our ponds and rivers.

16. Edentata. — The *Edentata*, or so-called toothless animals, are strange creatures unknown in Europe. They have few if any teeth, and feed on tiny insects. The most remarkable member of this family is the *great Ant Eater* (fig. 54), an inhabitant of South America. Its length sometimes attains 4 feet 9, not including the tail, which appendage measures about 2 feet 4 inches. It has no teeth whatever, but is provided with a long pointed tongue about 15 inches long, covered with slimy and sticky saliva; which it thrusts forth into ant hills or across their wonted paths. The unsuspecting ants that venture thereupon are condemned to death, being unable to free themselves, and when a sufficient number is thus caught the ant eater withdraws its tongue covered with its living burden into its mouth.

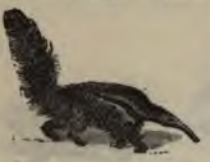

Fig. 54. — The great Ant Eater (South America). Lives on ants.

17. Rodentia. — We have now passed in review all the flesh eating animals, at least the most interesting among them. **1.** Let us now glance at the plant-eaters, or *Herbivorous animals*.

The first in order are the *Rodentia* or gnawing animals. Look at this picture, it represents a *rabbit's* head (fig. 55). **2.** In each jaw, you may observe two long teeth, which rub upon each other so as to gnaw vigorously whatever happens to come between them; the under jaw works backwards and forwards so as to produce the necessary rubbing and gnawing movement. This rubbing inevitably wears the teeth, only as they grow as fast as they wear out, they always remain the same length.

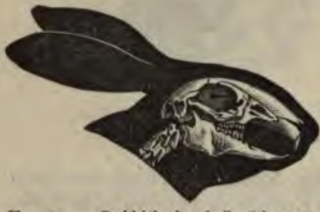

Fig. 55. — Rabbit's head (herbivorous gnawing animal).

The principal members of the rodent family that inhabit our country are: the *Squirrel* (fig. 56), nimble as a monkey, so gay, so pretty and so lively, in summer at least, — it sleeps in its nest all the winter through. The *Dormouse* (fig. 57), and the *Garden Dormouse*

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1. What name is given to plant eating animals? — 2. To what cause do the squirrel, rabbit and mouse owe their name of gnawing animals?

(fig. 58), are smaller than the squirrel, but quite as pretty and more dormant still. Then come the *Rats*, the *Mice*, the *Wood mice* and the *Field mice* (fig. 59), that have earned by their pilfering* such a deplorable reputation; then there are the *Hare* (fig. 60) and the *Rabbit*, well known by everybody, and the *Mountain rat or Marmot* (fig. 61), found in Alpine* regions, so celebrated for its sound hibernal sleep.

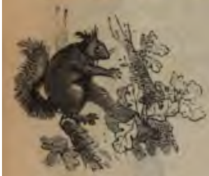


Fig. 56. — Squirrel. Rodent.

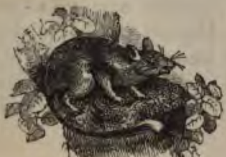


Fig. 57. — The Dormouse. Rodent.

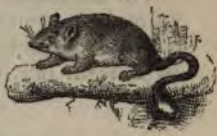


Fig. 58. — Garden Dormouse. Rodent.

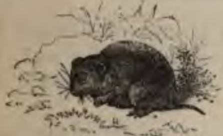


Fig. 59. — The Field mouse. Rodent.

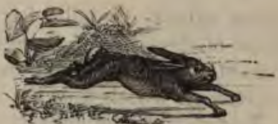


Fig. 60. — The Hare. Rodent.

We may also mention among European rodents, the *Beaver* (fig. 62). Some stray members of this family are to be found along the banks of the Rhone*, but their principal quarters are in North America. There they live in large colonies*; they construct dikes* upon the rivers, build themselves huts, cutting down the necessary wood with their powerful teeth, and working the clay

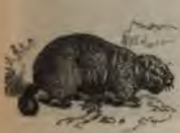


Fig. 61. — Marmot (Alps). Rodent.

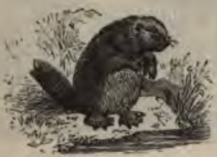


Fig. 62. — The Beaver (North America). Rodent.

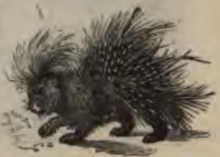


Fig. 63. — The Porcupine (Italy and Africa). Rodent.

with their broad scaly tails. In Italy and in Africa, *Porcupines* (fig. 63) exist; they sometimes weigh over 30 pounds, and their prickles are sometimes a foot long.

18. Horses. — *Horses* are real herbivorous or grazing animals, as you all know; the nature of their food might indeed be guessed by the mere examination of their back teeth (fig. 64). **1.** Instead of being like those of insect eaters, armed with sharp points or blades like those of flesh eaters, theirs are *quite flattened out*, and can but act as grind-stones to bruise the grains and grasses on which they feed.

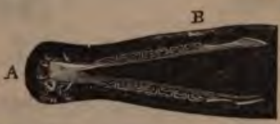


Fig. 64. — Lower jaw of a horse. A, front teeth; B, flat molar teeth (herbivorous).

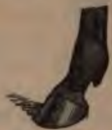
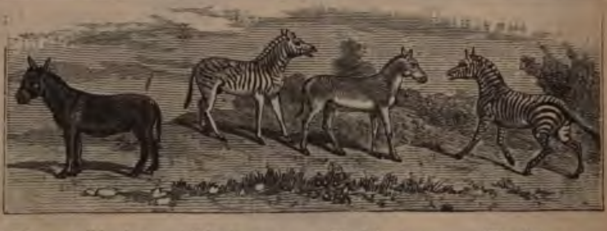


Fig. 65. — The horse has only one *toe* which terminates in a nail forming the hoof.

2. A distinctive character common to all of the horse kind, is that each foot has but *one toe*, ended by a sort of nail, which completely envelopes the extremity of the toe forming what is called the *hoof* (fig. 65).



g. 66. — 1. The Ass. 2. The Quagga. 3. The Hemionus. 4. The Zebra.

3. The principal genera of the horse kind are the *Horse*, properly so called, the *Ass* (fig. 66), the *Dauw*, the *Hemione*, the *Zebra*.

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1. What peculiarity do the molar teeth of horses present? — **2.** What *distinctive* character is common to horses? — **3.** Name the principal species of horses.

19. Ruminantia. — **1.** You have doubtless all seen a cow or a sheep *chewing the cud*, or *ruminating*, to use the scientific expression, that is to say, chewing, although they have apparently nothing to eat. I will explain to you how this happens. **2.** These animals eat very fast, and masticate* but imperfectly when doing so. When they have laid in, as it were, a sufficiency, and are at rest, they have the faculty of *bringing the food back into their mouth;* it is then chewed at leisure, so as to facilitate the digestion when finally swallowed.

The ruminating animals are almost all of rather considerable size, some are even enormous. **3.** Their molar* or back teeth are flat, like those of the horse; their stomach is composed of several pouches, and it is this peculiar character that allows *rumination*. **4.** Their feet have two toes, each of which is protected by a hoof (fig. 67). **5.** The first in order of this description that I will mention, is the *Camel*, two domesticated* species of which are well known: the *Camel with one hump*, or African *dromedary* (fig. 68), and the *Camel with two humps*, a native of Asia (69). Both of these are equally useful on account of their strength, their docility, and fitness for desert life.

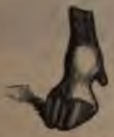

Fig. 67. — A foot with two toes. Ruminants (cows, sheep, camels, deer, giraffes, etc).

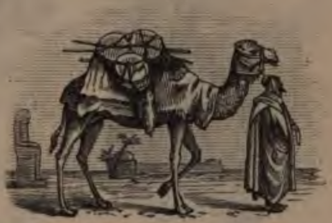

Fig. 68. — Camel with one hump, or African dromedary. Very useful. Ruminant.

In South America there exist animals that bear some resemblance to the Camel, only they are smaller, and have

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1. What is meant by the word *ruminating*? — 2. How does rumination take place? — 3. What peculiarities do the molar teeth of ruminants possess? — And their stomachs? — 4. How many toes have these animals? — 5. Tell me the different species of ruminating animals.

no hump at all. One species of these camel-like animals,

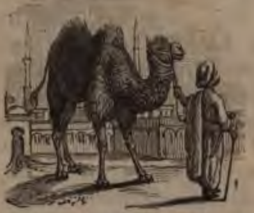

Fig. 69. — Camel with two humps (Asia). Is of great utility. Ruminant.

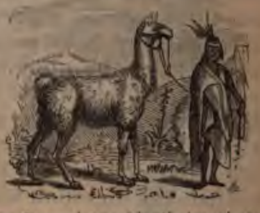

Fig. 70. — Lama (South America). Small camel-like animal without a hump. Ruminant.

the *Lama* (fig. 70), has been domesticated by the Indians.

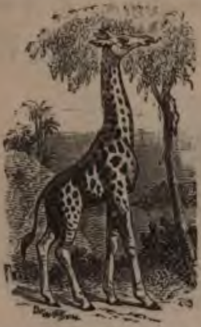

Fig. 71. — The Giraffe (Africa). H. from head to feet 18 feet.

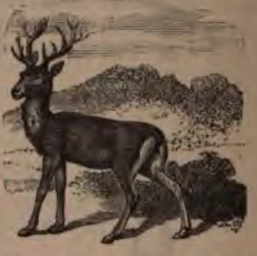

Fig. 72. — Red-Deer (Europe). Ruminant.

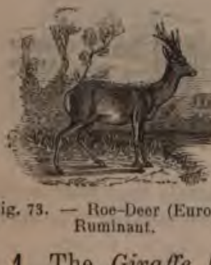

Fig. 73. — Roe-Deer (Europe). Ruminant.

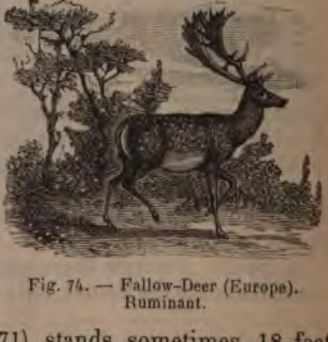

Fig. 74. — Fallow-Deer (Europe). Ruminant.

1. The *Giraffe* (fig. 71) stands sometimes 18 feet

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1. Tell me the different species of ruminating animals.

high; it is only to be found in Africa, and but one species is as yet known.

1. The *Deer family*, on the contrary, counts a great number of species, which are to be found in Europe, Asia, and America.

2. Their principal characteristic is that the head of the male is adorned with *solid horns*, which are in reality outgrowths of the bones of the skull, *that fall off and are renewed every year.* In Europe we have the *Red Deer* (fig. 72), the *Roe Deer* (fig. 73), the *Fallow Deer* (fig. 74), and in the northern regions the *Elk* (fig. 75), about the size of the horse, and the *Reindeer* (fig. 76), so useful in the icy wastes. The female of the Reindeer has horns like the male.

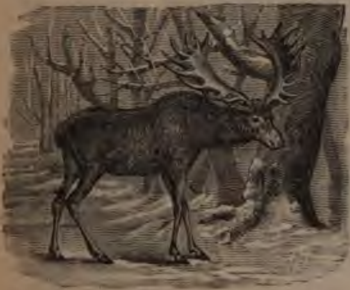

Fig. 75. — Elk (North of Europe). As large as a horse. Ruminant.

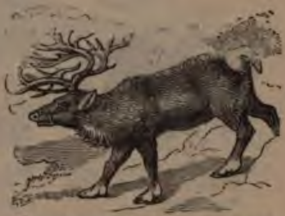

Fig. 76. — Rein-deer. Ruminant. A most useful animal in the icy regions.

3. See here is a cow's horn; it is a sort of *hollow sheath*. On the beast's head, this sheath fits over a sort of bony protuberance* of the forehead, which fills it exactly. The *protuberance and its sheath are never shed.* All the ruminantia that bear

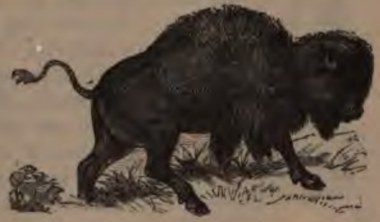

Fig. 77. — Bison (North America). — As large as an ox. Ruminant.

1. Tell me the different species of ruminating animals. — 2. What is remarkable about the horns of deer? — 3. What peculiarity do cows' horns present?

horns of similar description form a class apart, and are called *Hollow horned Ruminantia.*

Oxen are the largest animals of this kind, and also the most interesting. In Europe, in Africa, and in Asia several species have been domesticated. Notwithstanding there is still to be found, even in Europe, a big headed, humpbacked wild ox. This animal lives in the forests of Poland*, and is not unlike the *Bisons* (fig. 77), which inhabit in countless herds the prairies of North America.

Sheep and *Goats* are also be numbered amongst domestic animals. But there exists in the Alpine* mountains and in the Pyrenees*, a sort of wild goat (fig. 78), and in Corsica a wild sheep (fig. 79).

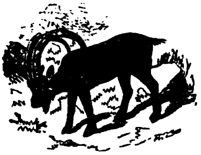
Fig. 78. — Bouquetin or Wild Goat of the Alps. Ruminant.

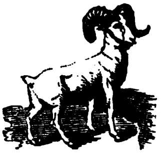
Fig. 79. — The Wild Sheep of Corsica. Ruminant.

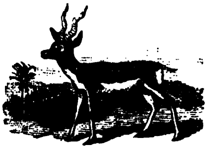
Fig. 80. — Gazelle. Ruminant.

Lastly, the general name of *Antelopes* is applied to a very numerous species of other hollow-horned ruminants of varied form and size, that live in herds in Africa. The African *Gazelle* (fig. 80), has a world-wide celebrity. One species of these agile and graceful creatures, natives of South Africa, when migrating from one place to another, travels in herds of about 20,000 head, carrying along in their ranks whatever they happen to meet. In Europe, only one species is to be found, that is the *Chamois* (fig. 81) of the Alps and Pyrenees.

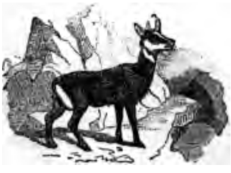
Fig. 81. — The Chamois of the Alps and Pyrenees. Ruminant.

20. Elephants. — **1**. The *Elephant* (fig. 82) is the largest of all land animals, it sometimes attains the weight of 14,000 pounds, and stands above 9 feet

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1. Which are the largest of land animals?

high. Everything is remarkable in this strange animal; the prolongation of the snout, which forms the long flexible trunk* it so cleverly uses; the two enormous teeth called *tusks*, that adorn its upper jaw, and which provide useful and beautiful ivory; their great intelligence and their easy taming; the great services they can render in carrying burdens at the chase or in war, etc.

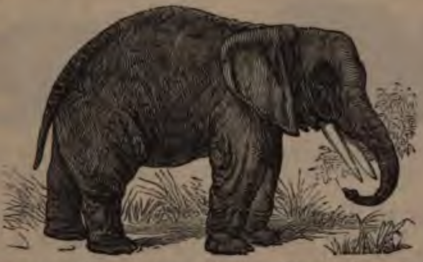

Fig. 82. — The Elephant of Africa. Weight 14,000 lbs. Stands 15 feet high.

Two species of this powerful auxiliary are known: one is a native of India and Ceylon, and is at the present day the only domesticated one. The other, with its large ear flaps and its prominent forehead, lives in Africa. The negroes make no use of it; although it was in ancient times much employed by the Greeks and Romans, and there is no reason why as much should not be done in our day.

21. Pigs. — **1.** There are other mammals besides those which we have mentioned, chief among which is the *Pig*. This creature is but a domesticated form of *Wild Boar* (fig. 83).

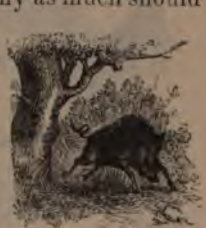

Fig. 83. — Wild Boar. Pachyderm.

2. Passing over the several species of wild boars that are found in Asia, Africa, and even in America, the most interesting of those remaining is the *Hippopotamus*.

The *Hippopotamus* (fig. 85) is very massive and

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1. What name is given to thick-skinned animals? — 2. Which are the most interesting of the so-called Pachydermata?

heavy, so much so indeed that on land it is scarcely able to walk. In the water, however, where it almost constantly lives, it becomes quite agile. It has an enormous mouth set with great massive teeth, which yield a precious sort of ivory. The hippopotamus is to be found in almost all the large rivers of Africa. These pig-like animals, like the *Rhinoceros* (fig. 84), have a thick leathery skin, for which reason they were once grouped together and called Pachydermata.

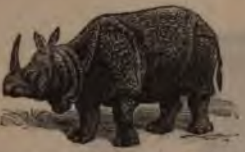

Fig. 84. — Rhinoceros. Pachydermata.

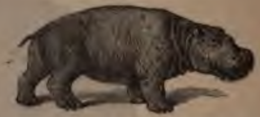

Fig. 85. — Hippopotamus (Rivers of Africa). Pachydermata.

This however is an error, for *the Rhinoceros*, strange as it may appear to you, is now known to belong to the same category as the horse.

22. Marsupialia.—1. In the great Australian island there exist, excepting the dog and some of the bat tribe, no mammalia having much resemblance to those of the other parts of the world. *The mammalia* found in Australia have quite peculiar characteristics.*

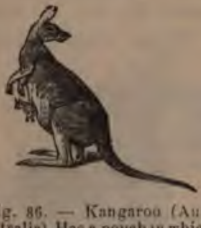

Fig. 86. — Kangaroo (Australia). Has a pouch in which its young are protected. Marsupialia.

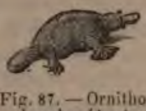

Fig. 87. — Ornithorhynchus (Australia). A duck's beak, webfooted.

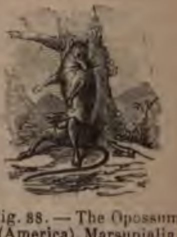

Fig. 88. — The Opossum (America). Marsupialia.

2. As in most cases the young of those animals, when newly born, take refuge in a sort of pouch (in

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1. What peculiarity do the mammals of Australia possess? — 2. Why is the name *Marsupialia* given to a group of Australian mammals?

latin, *marsupium*) situated under the mother's abdomen, the name of *marsupialia* has been given to the group.

Amongst Marsupialia there are *flesh eaters*, *insect eaters*, and also *grazing animals*.

The best known of these last is the *Kangaroo* (fig. 86), a strange creature, that with the help of its tail and enormous hind legs, is able to proceed by prodigious bounds, when pursued or otherwise pressed. The largest species of this animal attains the height of 6 feet, and even more.

Another strange Australian mammal is the *Ornithorhynchus* (fig. 87), whose jaws are enveloped as it were or transformed into a flattened bill like that of a duck; like the duck, it is also webfooted.

One only of the Marsupialia group is to be found out of Australia: it is the *Opossum* (fig. 88), a native of America; this little creature lives on flesh.

25. Seals. — All the animals that have until now occupied our attention live on land. **1.** True, the *Otter* seeks its prey under water: there also the *hippopotamus* passes a great part of its life; but although fond of bathing and river life, they come ashore, and walk and run on the dry land.

2. This is not the case with *Seals* (fig. 89): their feet, flattened out and fashioned like fins, enable them only to drag their bodies heavily along the ground. Almost the whole of their life is spent in the sea, and they swim and dive with marvellous agility. They live exclusively on fish.

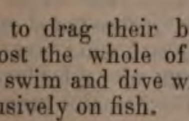

Fig. 89. — Seals. Live in bands, on the banks of rivers and in cold regions.

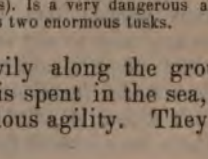

Fig. 90. — Walrus or sea-horse (North seas). Is a very dangerous animal. Has two enormous tusks.

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1. Amongst the mammalia already studied name two, that willingly stay in water although they come on dry land. — 2. Name some mammalia that pass nearly all their lives in water.

Some few seals are to be met with on our coasts, but in small groups only: their real home is on the icy shores of the northern seas of both hemispheres*, where they are wantonly and foolishly massacred. In 1870 the Scotch fishermen captured and killed 90,000 of these animals. The fat or oil of seals is used for industrial purposes, and their skin gives a beautiful fur. Some seals attain the length of 30 feet.

1. In the northern seas, there live, in herds also, animals akin to the seal; these are *walruses* or sea-horses (fig. 90), specially remarkable for the enormous tusks that adorn their upper jaw. They are very dangerous animals, sometimes more than 20 feet long, and when attacked in their native element they rush upon the boat, often upsetting it.

24. Cetacea. — Cetacea are mammalia that never come on shore, for they cannot live out of water; if they happen to be cast by some tempest upon the sea shore, they perish very rapidly. They are divided into two groups (fig. 91) *Whales* and *Porpoises*.

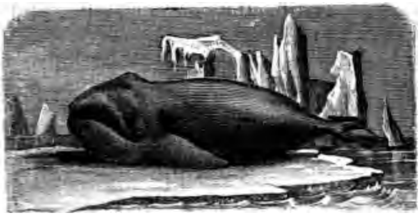

Fig. 91. — Whales. — They have no scales. — Fans or whalebone in the upper jaw, warm blooded. — Give milk to their young (mammalia) come to the surface of the water to breathe (aërial). — Sometimes are 107 feet long. — Very narrow throat. — Cetacean.

Many people have the idea that whales are fishes. Were any one to say so to you, Paul, what would you, answer? **2**. I would answer, *that fishes have scales, while whales have none*. Well, and what else? Ah! I don't know if whales have warm or cold blood. — **3**. They have *warm blood*. **4**. Then whales cannot be

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1. Mention one that is akin to the seal. — 2. In what way does the skin of the whale prove that it is not a fish? — 3. What deduction do you draw from the temperature of its blood? — 4. How does it feed its young? — In what manner does it breathe?

fish. Certainly not; besides *they give milk to their young*, and are *moreover obliged to come to the surface to breathe*; for they would die by drowning were they to remain under water for more than half an hour. You see a whale is not only an **aërial** animal, but also a **mammalia.**

But the Cetacea are strange members of the mammalian family. **1.** They have the outward form of a fish, the tail has become a fin, only it is placed horizontally* instead of being vertical*, like that of a fish. **2.** Their fore limbs are fashioned like oars or fins, whilst the hind ones are totally wanting.

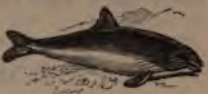

Fig. 92. — Porpoise or Dolphin. Live on fish. Cetacean.

3. Amongst cetaceans some have teeth, and devour prodigious numbers of fishes. *Porpoises* and *Dolphins* (fig. 92) are of this category. Many of these animals are to be seen playing and rolling in the sea around our coasts.

A large cetacean, the *Cachalot* or *Spermaceti whale* (fig. 93), has teeth in the under jaw. It is sometimes 75 feet long, and is very dangerous.

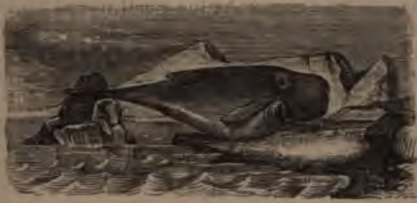

Fig. 93. — Cachalot or sperm whale has teeth in the underjaw. Is sometimes 75 feet long. — Is very dangerous. — Cetacean.

4. *Whales*, properly so called, have no teeth; only *the roof of their mouth* is set instead with several rows of long, flat, and flexible horny growths called *fans*, which are utilised under the name of *whalebone*. These enormous animals have been known to attain the great length of 107 feet, and to weigh 500 000 pounds, which is about equivalent to that of 40 elephants.

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1. What shape is the tail of cetacea? — 2. What do their fore-feet serve them for? — 3. Name two cetaceans that have teeth. — 4. What take the place of teeth in whales?

1. [illegible] they feed almost [illegible] marine creatures, that float [illegible] of the sea. Why so? [illegible] the whales not eat [illegible] of them? Well, it is [illegible] them to [illegible] find room to [illegible]

2. [illegible] of their fans, [illegible] skin and pro-[illegible]

[illegible] — MAMMALIA.

1. **Mankind** [illegible] — Man belongs to the Mammalian group.

2. [illegible] among men the *white* Europeans [illegible] of Africa, and the *red skins* [illegible]

3. [illegible]

4. **Monkeys** [illegible] — [illegible] **Monkeys**, are three [illegible] the African *Gorilla* and [illegible]

5. [illegible] monkeys are extremely numerous.

6. [illegible] in warm climates.

7. **Bats** [illegible] — Bats are [illegible] mammalia. They are [illegible] ears and teeth: their wings [illegible] membrane which is a prolongation [illegible] and which is stretched out upon elongated [illegible]

8. [illegible] During the night they fly abroad in [illegible] they feed. Therefore they are useful to [illegible]

9. **Insectivorous mammals** [illegible]. — Other insectivorous animals [illegible] insects: they are all small. Among them we may mention the *Hedgehog*, whose skin is covered with prickles, — the sharp-nosed *Field mouse*, — the *Mole*, which swallows enormous numbers of white worms, and by no means eats the roots of plants as people generally imagine.

10. **Carnivorous mammals** (p. 25). — The **Carnivorous** (Latin: *Carnis*, flesh) live upon flesh.

11. Their paws are very strong, and armed with sharp and powerful nails called claws; their mouth is set with long, strong, and sharp teeth.

12. The best type of these animals is the **Cat** species (p. 26). The

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1. On what do they live? — 2. What articles o commerce do we derive from the whale?

Tiger (the fiercest of wild beasts), the *Lion*, the *Panther*, the *Jaguar*, all three less dangerous to mankind than the Tiger, are in reality but very big and powerful Cats.

13. Next to the cats, we find **Dogs**, in which species are ranged : the *Wolf*, dangerous in Asia and in Russia; the *Fox* and the *Jackal*, great ravagers of poultry yards.

14. The **Hyenas** (p. 28), are fonder of dead bodies than of live flesh.

15. The **Brown Bear** (p. 28), in the Alps and Pyrenees, prefers fruit and honey to the flesh of man or that of his flocks and herds. On the contrary, the *White Bear* of the icy regions, and the *Grizzly Bear* of North America prefer mankind to any other prey.

16. **Edentata** (p. 30). — The **Edentata**, that possess few if any teeth, are unknown in European countries. The most interesting member of the group is the *Great Ant Eater*, whose long worm-shaped tongue proves fatal to all ants that venture upon it on account of the slimy substance it secretes.

17. **Herbivorous mammals** (p. 32). — The **Herbivora** feed upon grasses.

18. The first in order among those are the **gnawing animals**, such as Rabbits, Squirrels, Dormice, Rats, Mice, Beavers, Marmots.

19. The **Horse tribe** (p. 32) which includes the Ass, have flat back teeth; on each foot, but one finger or toe exists, which is completely enveloped by a terminal nail. This nail forms the *hoof*.

20. **Ruminantia** (p. 33) so called because they *ruminate* or *chew their cud*, which action consists in chewing food which has been previously swallowed.

21. The teeth of ruminants are flattened like those of the horse tribe; their stomach is composed of several pouches; each foot has *two toes*, terminated each by a hoof, and they are hence called cloven footed.

22. The Ruminants include : the *one humped Camel* or African *Dromedary*, and *the two humped* Asiatic *Camel*, which afford in their native countries the services horses render in ours; the *Lama* of South America, domesticated by the Indians; the *Giraffe* of Africa, that stands 18 feet high; the *Deer*, *Roe-deer*, *Fallow Deer*, *Elk* and *Rein-deer*, which are used as beasts of burden in the Polar regions. All these have solid horns that fall off and are renewed every year; *oxen*, *bisons*, that are to be found in herds in the prairies of North America; *Sheep* and *Goats*; — *Antelopes*; — the *Chamois* of the Alps and Pyrenees, all having hollow horns that last all their life long.

23. **Elephants** (p. 36). — The **Elephants** are the largest of all terrestrial animals. They render great services in carrying heavy burdens. In Africa a wild species is to be found, whilst the Asiatic species has been domesticated.

24. **Pigs**. — Among the *Pig* kind we have the *Wild Boar* and the *Hippopotamus*. The *Rhinoceros* was formerly classed with them on account of the thickness of its skin, but this is no longer the case, as that animal is now known to be related to the horse.

25. Marsupialia (p. 38). — The **Marsupialia**, excepting one species, are Australian animals. They have a pouch (marsupium) under their abdomen, in which they carry their young. The best known amongst them is the *Kangaroo*. The *Opossum* alone is a native of America.

26. Seals (p. 39). — The **Seals** spend the greater part of their life in the water. They live in herds on the shores of the northern seas, where they are massacred in countless numbers in order to obtain their oil and their skin. The Morse, with its long tusks, is ranked alongside with the seal.

27. Cetaceans (p. 40). — The **Cetacea** or **whale** tribe comprises *Dolphins*, *Spermaceti whales* and *Whales* properly so called.

28. *Whales* are not fishes. They have no scales (whilst fishes have); they have warm blood (fishes, cold blood), they give milk to their young, and would be drowned were they to remain longer than half an hour under water : they are *mammalia*, and *air breathing* animals.

29. Whales have, hanging down from the roof of the mouth, several rows of that material used in commerce under the name of whalebone, each row consisting of several hundreds of fringes. Their throats are extremely narrow. The other Cetaceans have teeth.

VERTEBRATES. — 2 Birds.

25. Birds, as we have already said, are easily recognised, for they all possess a beak, feathers, two wings and two feet.

The *beak*, as you can easily see upon this fowl's head I have prepared for the lesson, is merely a sort of horny sheath that covers over or envelops the two jaws.

The *feathers* when in a state of full development have a tube by which they are implanted in the skin; this tube is continued by a full stalk, bearing on either side a row of *vanes*; those in their turn bear smaller *vanes*, and those sometimes, as is the case with goose feather, bear smaller ones still. All these vanes adhere together, and are woven into one another. All feathers however are not so complete as these.

The *wings* are generally strong enough to allow the bird to fly. Some, however, like those of the ostrich, are too short to allow their owner to rise off the ground. Some birds use their wings as fins, and swim with their aid under water.

All birds lay *eggs*, and most of them construct *nests*. — **1**. The egg is principally composed of a *stony shell*, a *white* part and a *yellow* part or *yolk*. See, here are two hen's eggs. The one raw, the other cooked hard. I have broken the shell of the raw one, and its contents have run out all over the plate. Do you see in the yolk that little white speck. **2**. It is the **germ**, and would have become a little chicken had we left it long enough to be hatched under the mother hen. I shall now take the shell off the *hard boiled egg*, and carefully cut it in two, so that you may see the position of the yolk and the white.

3. When an egg is kept in a warm place, during a certain length of time, the little white germ becomes a tiny bird that grows in its prison, and as it grows gradually absorbs the white and the yolk until it becomes big enough to fill the shell, which it then breaks with its beak. **4**. Thence it comes out in some cases blind and almost motionless, like the young pigeon (fig. 94), in others lively and nimble, knowing how to forage out food for itself and able to run about, like the chicken (fig. 95), or even to swim, like the duck.

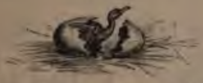
Fig. 94. — Pigeon coming out of its egg. It is blind and cannot move.

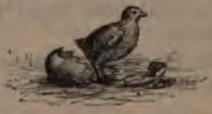
Fig. 95. — Chicken coming out of its egg. Can walk.

5. In the natural course of things, it is the mother bird that furnishes the heat necessary for *hatching* the eggs; she it is that sits upon them, and that builds the nest where eggs and young will be sheltered and kept warm. The shapes and sizes of those nests vary, according to the species of the builder. **6**. But you know that eggs can be hatched by artificial heat in *boxes* made for the purpose (fig. 96).

7. And this is not all I have to tell you about our

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1. What is a bird's egg composed of? — **2**. What is the little white speck seen in the yolk of an egg? — **3**. What happens when an egg is kept warm for a certain time? — **4**. In what state does the young bird come out of the egg? — **5**. How is the heat generally furnished for hatching eggs? — **6**. Do any other means exist? — **7**. Name some birds of passage.

feathered friends. Some of them *undertake long journeys*, very regularly, every year; they migrate as we say. Thus, swallows come to our country in the summer time to lay their eggs and bring up their young; when winter draws near, and insects become scarce, they fly off again, and return to the warmer climate of Africa. So do the *Quails*, the *Nightingales* and many others. Some on the contrary visit our country only in winter, when severe cold drives them from the far north: the wild ducks, wild geese, and swans are of this class.

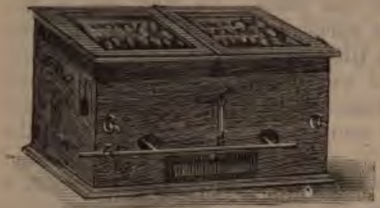

Fig. 96. — Box for hatching chickens by artificial heat. The warmth of the mother is replaced by the stove.

We will now rapidly glance at the principal groups of birds.

26. Birds of Prey. — Some birds live exclusively upon the live *flesh* of other birds, of quadrupeds*, or of reptiles*. **1**. They are for this reason called *Birds of Prey*. **2**. They are marvellously supplied with weapons wherewith to accomplish their work of destruction: they have sharp hooked *beaks* (fig. 97), long and piercing claws called *talons* (fig. 98), and long pointed *wings*. They fly so swiftly and for such a length of time that a falcon once lost in the forest of Fontainebleau, in the centre of France, was found the following day at Malta.

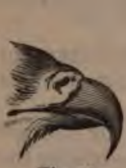

Fig. 97.
Beak of a bird of prey, sharp and hooked.

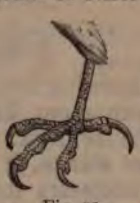

Fig. 98.
Claws of a bird of prey, long piercing talons.

3. Some birds of prey* hunt for their food in the day-

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1. What name is given to those birds that feed entirely on flesh? — 2. What natural weapons have they *to accomplish* their work of destruction? — 3. What name is given to those birds of prey that hunt their food in the day time? And to those that hunt by night?

time, and are for that reason called *diurnal;* others hunt after night fall, and are called *nocturnal.*

1. Amongst *diurnal* birds of prey, we find *Vultures* (fig. 99), that feed on the flesh of dead animals. Some very large species of these birds exist in Europe. In warm countries they render real service in clearing away dead bodies that would otherwise infect the air. The *Condor* of South America (fig. 100), is the largest bird that flies: it sometimes measures from one tip of its outspread wings to the other 12 feet; the *Vulture* of the Alps (fig. 101) is almost as large. *Eagles* (fig. 102) have stronger wings and talons than vultures; they are also bolder, and feed on live prey. *Falcons* (fig. 103) are stronger still, proportionately to their size, and more daring. In former times they used to be trained to hunt in our country, and are so still in Algeria and in the East. The *Hawk* (fig. 104), the *Buzzard* (fig. 105), the *Sparrow*

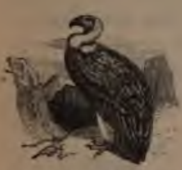
Fig. 99. — Vulture.

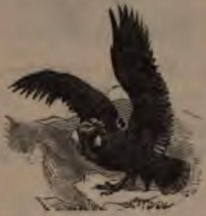
Fig. 100. — Condor (South America).

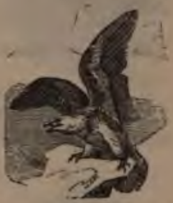
Fig. 101. — Bearded Vulture of the Alps.

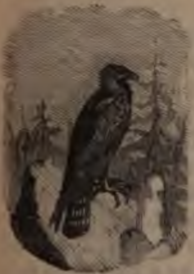
Fig. 102. — Eagle.

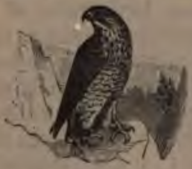
Fig. 103. — Falcon.

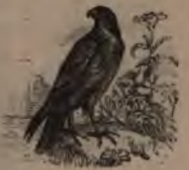
Fig. 104. — Hawk.

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1. Mention some diurnal birds of prey.

hawk (fig. 106), and the *Kite* (fig. 107), are much less strong

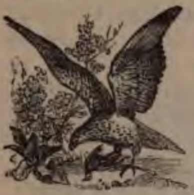
Fig. 105. — Buzzard.

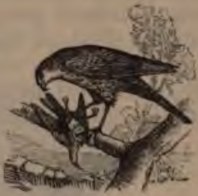
Fig. 106. — Sparrow hawk.

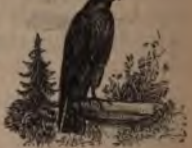
Fig. 107. — Kite.

1. *Nocturnal* birds of prey have a soft downy plumage which allows their flight to be quite noiseless: the openings of their ears are very wide, and their big round eyes are directed towards the front. They all come under the general name of *Owl* (fig. 108). Some have tufts of feathers AB, that stand erect on either side of the head, and are called *horns;* others, such as the barn owl, have no such ornament (fig. 109). A good many species of these birds live in our country, from the *Great Eagle Owl* (fig. 110) almost as big as a turkey to one (fig. 111) about the size of a blackbird. **2**. They make not a little havoc amongst rats, mice, and other destructive animals of small size; this should induce people to protect

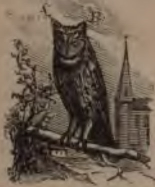
Fig. 108. — Common Owl.

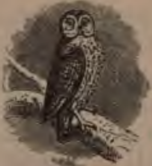
Fig. 109. — The Barn Owl.

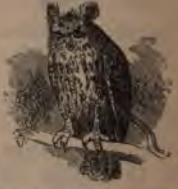
Fig. 110. — Great Eagle Owl.

Fig. 111. — Small kind of Owl. Size of a blackbird.

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1. Name some nocturnal birds of prey. — 2. Why ought they not be destroyed?

them instead of nailing them up on barn* doors, as is the stupid custom in some places.

27. Parrots. — *Parrots* (fig. 112) are characterised by their short clumsy beak, their fleshy tongue, which allows them to articulate words, and their toes turned two forwards and two backwards, allowing them to climb with ease. Their remarkable intelligence has justly enough entitled them to be called the *feathered monkeys*. Like monkeys, they are natives of warm countries, and their noisy and gaudy bands people the intertropical* forests of the old and the new world.

Fig. 112. — Ara : Parrot.

28. Pigeons. — *Pigeons* in their natural state are neither of great variety nor of a great number of species. In this country we have the *Turtle dove* (fig. 113), and *Pigeons*, which last have been domesticated.

Fig. 113. — Turtle dove.

29. Gallinaceans. — The name of *Gallinacean* (from the Latin *gallina*, the hen) has been given to the birds of this group on account of their greater or less resemblance to the *Hen*, which has been taken as a type. They are grain-eating birds. Our hens are supposed to have originally come from India. *Pheasants* (fig. 114) also, as well as *Peacocks* (fig. 115). The *Guinea fowl* (fig. 116) came from Africa, and the *Turkey* (fig. 117) from America. In our country are to be found the common *Partridge*, and the *Quail* (fig. 118);

Fig. 114. — Pheasant.

Fig. 115. — Peacock.

Fig. 116. — Guinea-fowl.

and in the North, on the mountains, the *Heath-cock* (fig. 119), the *Ptarmigan*, etc.

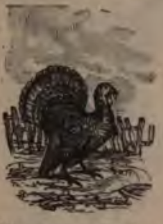
Fig. 117. — Turkey.

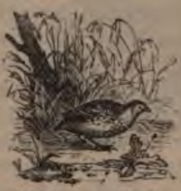
Fig. 118. — Quail.

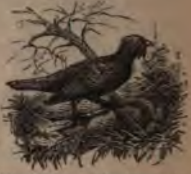
Fig. 119. — Heath-cock.

30. Wading-birds. — The *Wading-birds* are so called on account of their long naked legs. Most of *them live in* marshy places, and wade through mud

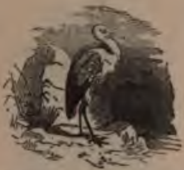
Fig. 120. — Stork.

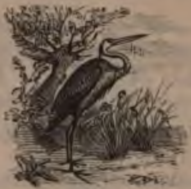
Fig. 121. — Heron.

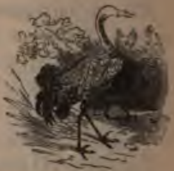
Fig. 122. — Crane.

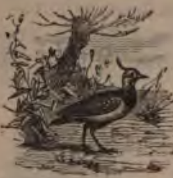
Fig. 123. — Lapwing.

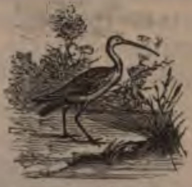
Fig. 124. — The Curlew.

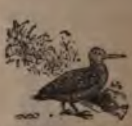
Fig. 125. — Snipe.

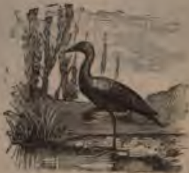
Fig. 126. — The Water hen.

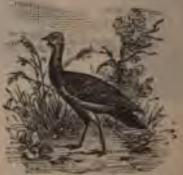
Fig. 127. — Bustard.

and water; they are mostly provided with long necks and beaks, so formed as to enable them to catch, notwithstanding their long legs, the small animals on which they feed. Those best known in our country are the *Stork* (fig. 120), the *Heron* (fig. 121), the *Crane* (fig. 122), the *Lapwing* (fig. 123), the *Curlew* (fig. 124), the *Snipe* (fig. 125), the *Water hen* (fig. 126), the *Bustard* (fig. 127), etc.

51. Ostriches. — *Ostriches* are big birds, whose wings, although too short for flight, help them to run with great rapidity.

The *Ostrich* is a native of Africa, it has but two toes (fig. 128). It attains the height of more than 7 feet. The Rhea, an American ostrich (fig. 129), is of smaller size, and has three toes. The *Cassowary* of Australia* and Borneo* (fig. 130)* is larger, but of a clumsier make than the Rhea.

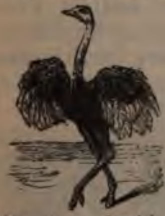

Fig. 128. — Ostrich (Africa). Height 7 feet.

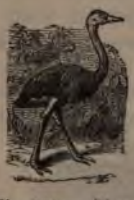

Fig. 129. — Rhea (America).

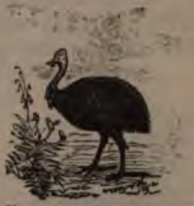

Fig. 130. — Cassowary (Australia).

Great in size though these birds are, they seem quite small beside some of their species, near neighbours to the Cassowary, which the natives of Madagascar* and New Zealand (fig. 131)* have exterminated. They are nowhere to be found at the present day, and all that remains to tell what they were, are a few of their bones and some of their eggs. But what eggs they are! One single egg, is about equal to six ostrich eggs, or to come nearer home, to a hundred and fifty hen's eggs.

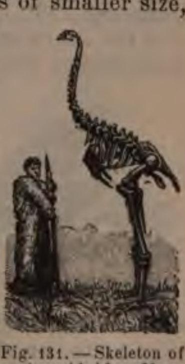

Fig. 131. — Skeleton of a large bird from New-Zealand. — Exterminated. — Height about 10 feet.

52. Palmipeds. — *Webfooted birds.* These have, as their name indicates, *palmated or webbed feet* (fig. 132), that is to say, their toes are united to one another by a skin or web. This allows them to swim easily. Look at this duck's foot: when the bird draws it forward, it folds it up nicely so as to pass through the water without forming the slightest obstacle; when pushed backwards, it spreads itself out on the contrary, offers a resistance, and the bird is thereby propelled forward.

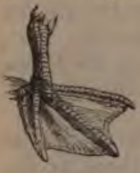
Fig. 132. A webbed foot.

Ducks (fig. 133), *Geese* (fig. 134), and *Swans* (fig. 135) are Palmipeds that swim to perfection, fly very well, but walk very badly. They have a broad bill provided with a sort of tiny blade that answer the purpose of rudimentary teeth. *Sea gulls* (fig. 136), that live almost always on the seashore, and the enormous *Albatross* of the South seas (fig. 137), have pointed bills; they also are excellent fliers. The *Pelican* (fig. 138) and the *Cormorant* (fig. 139), are even more completely webfooted than the foregoing, for the web envelops not only the three foretoes, but even the first or great toe also.

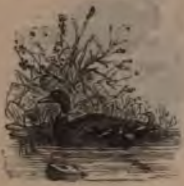
Fig. 133. — Duck.

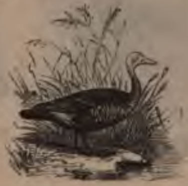
Fig. 134. — Goose.

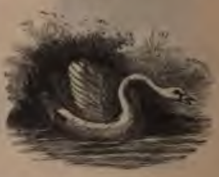
Fig. 135. — Swan.

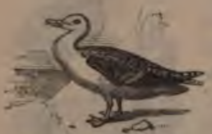
Fig. 136. — Sea-Gull.

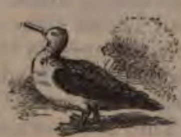
Fig. 137. — Albatross.

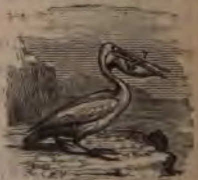
Fig. 138. — Pelican.

Upon the shores of the Northern seas the *Penguins* (*fig.* 140) are to be seen in myriads; and in the South seas the *Awks* (fig. 141), are quite as numerous. Neither species can fly. This is not because their wings are too weak to carry them, as is the case with the

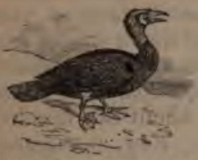
Fig. 139. — Cormorant.

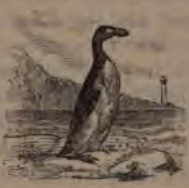
Fig. 140. — Penguin.

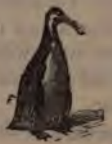
Fig. 141. — Awk.

ostrich, they are, on the contrary, very strong; but they have no real feathers upon them, and the bird only uses them as fins, and swims with them under water.

55. Passerines. — Or *Sparrows.* This name is given to a great number of genera of birds that are neither birds of prey nor palmipeds, etc. The Passerines in fact include most of the small birds in existence.

Some members of this tribe have two toes in the front, two others turned backwards, which enable them to climb admirably along the trunks of trees: such is the *Wood pecker* (fig. 142), very unjustly accused of damaging the trees of our forests, whilst in reality he merely searches out the holes that the insects have already made.

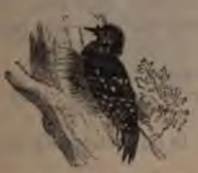
Fig. 142. — Wood pecker.

Fig. 143. — Crow.

Some others have a hooked beak like birds of prey, such is the *Shrike*. Others have a delicate beak, sometimes pretty long, by which they manage very cleverly to catch insects: such are the *Blackbirds*, *Warblers* and *Nightingales* of our country; also the *Humming birds* of America, so brilliant and so tiny that the smallest is not bigger than a drone, etc., etc. Others have a widely-opening beak, well adapted for hunting gnats; this is the case with the *Swallows*. Others again have a strong, short, thick beak, with which they eat grains of all sorts : these are the *Lark*, the *House Sparrow*, the *Chaffinch*, the *Titmouse*, the *Bull-finch*, etc. Others can use their powerful beaks like a sort of pick axe, with which they turn up the earth and tear to pieces dead bodies, such are the *Magpies*, *Jays*, etc., *Crows* (fig. 143). In this country we have about two hundred species of this very interesting group. Few, even among sportsmen, are aware that we possess such a variety.

SUMMARY. — BIRDS.

1. **Generalities** (p. 44). — **Birds** have a horny *beak*, feathers, two feet, two wings; they lay *eggs*.

2. Eggs are enclosed in an earthy shell, and consist of a white part and a yolk. — In the yolk floats a tiny white speck called the *germ*, which will become the chicken when the egg is hatched.

3. In the natural course of things, it is the hen that affords the heat necessary for the *hatching* of the egg; but eggs can be artifically hatched in boxes made for the purpose.

4. **Birds of prey** (p. 46). — **Birds of prey** have a sharp hooked beak, toes provided with long sharp nails, called *claws or talons*, long and pointed wings. They fly with great rapidity.

5. Some hunt during the day time, and are called *diurnal;* others pursue their prey after night fall, and are called *nocturnal* birds.

6. Amongst diurnal birds we find *Vultures*, that feed on dead animals. *Eagles*, that feed on live prey; *Falcons*, that were formerly trained for the chase.

7. Amongst the nocturnal birds of prey are *Owls*.

8. Owls of all descriptions destroy rats and mice : they ought therefore to be preserved.

9. **Parrots** (p. 49). — **Parrots** are to be found only in warm climates.

10. **Pigeons** (p. 49). — **Pigeons**, natives of our country : are *Wood pigeon*, the *Turtle dove*, and the *Rock dove*.

11. **Gallinaceans** (p. 49). — The **Gallinaceans** (*gallina*, hen). Under this head are generally grouped birds that more or less resemble the Hen : *Pheasants*, *Peacocks*, or *Guinea fowls*, *Turkeys*, *Partridges*

12. **Wading birds** (p. 50). — Most **wading birds** are perched upon long slender legs. Those best known are *Storks, Herons*, *Cranes, Snipe*.

13. Ostriches (p. 51). — **Ostriches** are large birds. The species found in Africa sometimes stands 7 or more feet high. Their wings are too short to be used in flight, but they run very swiftly.

14. Palmipeds (p. 51). — **Palmipeds**, or *webfooted* birds, have, as their name indicates, *palmated* or *webbed feet;* that is to say, have their toes enveloped or united by a film or web. This allows the birds of this tribe to swim with great ease. *Ducks, Geese*, and *Swans* are Palmipeds.

15. Sparrows (p. 53). — Under this name is included a great variety of species: *Blackbirds, Warblers, Nightingales, Swallows, Larks, Finches, Crows*, etc.

VERTEBRATES. — 3 Reptiles.

34. In their shape and outward appearance *Reptiles* differ very considerably from one another. There are *Tortoises*, that have a horny* beak like a bird, four feet and a carapace, in which their body is enclosed; *Lizards*, that have teeth and limbs, but no carapace; *Serpents*, that have neither carapace* nor limbs. All reptiles lay eggs somewhat similar to those of birds, only the shell instead of being earthy is horny.

35. Tortoises. — Some Tortoises live on land; others are to be found in marshes and in fresh water; others again, called *Turtles*, live in the sea (fig. 144). They are encased in a flat carapace that offers but little resistance to the water through which the animal moves, propelled by its long, flattened, paddle-like limbs. Upon some parts of the American coasts countless multitudes of these turtles resort to deposit their eggs: there they are captured for their flesh, to make soup, and for their shells, which furnish the precious tortoise shell.

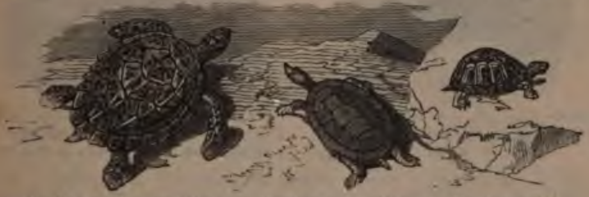

Fig. 144. — Sea-tortoise, or Turtle. Fresh water-tortoise. Earth tortoise.

The land *Tortoises* have short limbs and more convex carapaces, which last are so strong and resisting that a man may stand upon the back of a tortoise 4 inches long, without harming it. In Africa some are found 3 feet long.

Freshwater Tortoises are, in shape, intermediate between the Turtle and the land Tortoise.

36. Lizards. — **1.** The largest of this group is the *Crocodile* (fig. 145), powerful enough to be very formidable even to mankind. The large rivers of Africa, Asia and America swarm with them, and some attain the length of above 24 feet.

Fig. 145. — Crocodile. Some are 24 feet long.

Amongst the many species of the lizard tribe the most curious is the *Chameleon* (fig. 146). This strange creature is very common in Syria, and on the southern coasts of the Mediterranean. It owes its world-wide celebrity to its faculty of rapidly changing colour according to circumstances. Anger or calm, sun or shade have influence upon it, and cause it to become green, yellow, black, etc. In this country only two kinds of lizards are found (fig. 147).

Fig. 146. — Chameleon. Changes colour.

Fig. 147. — Lizard. Their tails grow again after having been broken off.

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1. Name a large lizard very formidable to man.

1. Lizards present a strange phenomenon : their tail, brittle and easily broken, lives for a considerable length of time after being separated from its bearer's body ; and more than that, *the lost tail is in a relatively short time replaced by another similar to the amputated one.* This is certainly most convenient, and a great pity it is that mankind cannot renew broken limbs after the same fashion.

The Slow Worm, or Blind Worm, although altogether deprived of limbs, is also a lizard. It is so very brittle that one can scarce touch it without breaking its tail.

57. Serpents. — **2**. There are some serpents whose bite, accompanied by the emission* of a liquid poison called *venom*, occasions accidents, often dangerous and may be mortal* ; they have been therefore deservedly called *venomous Serpents*.

Others do not bite, but coil themselves tightly around their prey : such are dangerous only when of very considerable size. The *Boa* of South America (fig. 148), the *Python* of Africa, and some other species, are of this class ; some have been known to attain 36 feet in length. **3**. These enormous reptiles, by the mere pressure of their tightened folds can kill an ox with the greatest ease, and man is but small game to them. **4**. Our *Ring snakes* (fig. 149) are much smaller and quite

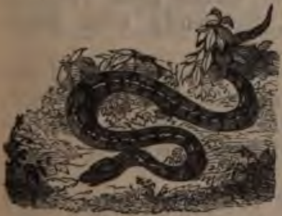

Fig. 148. — Boa of South America. Sometimes measures 36 feet.

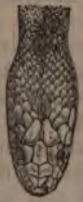

Fig 149. — Head of a ring snake.

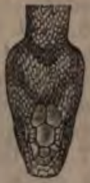

Fig. 150. — Head of a viper.

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1. What peculiarity does the tail of the lizard present? — **2**. What name is given to serpents, whose bite might prove deadly? — **3**. Does the boa destroy its victims in the same manner as venomous serpents? — **4**. Why are our ring-snakes inoffensive?

inoffensive. The *Snakes* of our European regions are all of small dimensions : the longest rarely attaining 6 feet in length.

1. In Europe happily but one venomous serpent exists, the *Viper* (fig. 150), and it is one of the least dangerous. **2**. The venom is a liquid that accumulates in a small pouch (A, fig. 151) situate at the root of a long and very sharp tooth B, through, **3**. which runs a sinuous canal. **4** When the animal bites, the tooth presses on the pouch A, a drop of the venom enters the canal and penetrates with the tooth into the wound. The extraction of this tooth (there is one on each side) renders the bite perfectly harmless; and this is how jugglers allow themselves to be bitten by deadly serpents to the great amazement of the spectators.

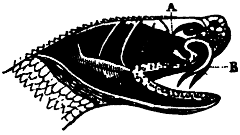

Fig. 151. — Head of a viper.
A, pouch where the venom accumulates.
B, tooth very pointed and pierced by a passage through which the venom flows.

5. Viper's venom gives fever, causes great swelling and sometimes mortification, frequently even death ensues.

6. But this venom is weak compared to that of the *Horned Adder* of the African deserts, the *Fer de lance*, of Martinique*, the *Rattle Snake* of America, the *Cobra* of India. The bite of all those species is almost always rapidly fatal to man.

7. In the course of the year 1875, the Cobra caused the death of 26,000 persons in British India. The whole country swarms with them. This reptile has no warning rattle, like that of the rattle snake, but can stealthily fall upon the unwary passer-by.

---

1. Mention a venomous serpent of our country. — 2. Where does the venom accumulate ? — 3. What peculiarity is there about the pointed tooth of a serpent? — 4. By what means do they use the venom ? — 5. What effect is produced by the venom of the viper? — 6, 7. Are there any serpents still more dangerous than vipers?

SUMMARY. — Reptiles.

1. **Reptiles** differ greatly in shape from one another. The group comprises *Tortoises*, *Lizards*, and *Serpents*.

2. **Tortoises** (p. 55). — **Tortoises** and Turtles have a horny beak, similar to that of birds, four feet, and a carapace, in which they are, as it were, enclosed.

3. Some of these animals live on the land, some in marshy places and freshwater, others in the sea. These last sometimes attain the length of 6 feet.

4. **Lizards** (p. 56). — The largest of the *Lizard* family are the *Crocodiles,* which sometimes attain the length of 24 feet. These animals are dangerous to mankind.

5. The *Chameleon* of Algeria can change its colour according to circumstances, if it be angry or calm, in full sunlight or in the shade.

6. Common **Lizards** have very brittle tails, easily separated from the body; only these appendices grow again, and regain their primitive dimensions.

7. **Serpents** (p. 57). — Some *Serpents* are venomous, others are not so.

8. Amongst serpents that have no venom we find the *Boa* of South America and the *Python* of Africa. Those species sometimes attain the great length of 36 feet; they are able to kill even large animals by coiling themselves around their victims, and thus suffocating them.

9. The *Snakes* of our country are quite harmless.

10. It is not so with the *Viper*, whose venom causes fever, great swelling, sometimes mortification, sometimes even death.

This venom is contained in a sort of pouch or gland situated at the root of a long, sharp, hollow tooth. When the animal bites, the tooth presses on the pouch, a drop of venom enters the canal that runs through the tooth, and penetrates with the tooth into the wound.

VERTEBRATES. — 4 Amphibians.

38. Metamorphoses of Amphibians. — 1. We have already seen that the animals belonging to this group are *aquatic** when young, and *aërial** when full grown. 2. Between these two stages of life they undergo remarkable changes in their outward con-

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1. What does the word *Amphibian* mean? — 2. What phenomena do these animals present?

figuration, as well as in their mode of life: these changes are called *metamorphoses.*

The most complete examples of metamorphoses are presented by *Toads* (fig. 152), the common *Frogs,* and the *Green* or *Tree Frogs.*

1. You have all certainly seen frog's eggs (fig. 153, A), and you know that they have no hard shell, but are soft and coated in a slimy envelope. **2**. After a certain time the egg gives birth to a little black creature B, that in the space of a few days becomes excessively brisk and lively. **3**. It grows rapidly, and displays a long fish-like tail, with a body and head all in one big ball C, D, E. **4**. It has no limbs whatever; shortly, however, legs and feet make their appearance, the hind ones first. **5**. As the legs grow, the tail gradually diminishes, until at last the animal is in possession of four full-sized legs, and has entirely lost both its tail and its gills,-the place of these latter being taken by lungs. The *Tadpole* has become a Frog, or a Toad, E, F. **6**. Originally *aquatic,* it has become *aërial :* the *grass eater* or *herbivorous**

Fig. 152. — Toad.

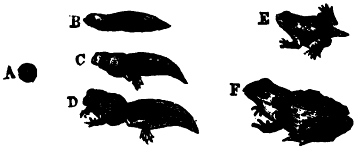

Fig. 153. — Transformation of a frog's egg. A, frog's egg. — B, C, D, tadpoles. — E, tadpole become frog. — F, frog.

Fig. 154. — Triton or Water Newt.

Fig. 155. — Continental Salamander.

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1. What is the first state of the frog? — 2. What comes out of the egg? — 3. What change soon takes *place in the* little animal? — 4. How do the feet make their appearance? — 5. What becomes of the tail? — 6. Explain the different transformations respecting respiration and food.

creature has become a *flesh-eating* or *carnivorous** *animal.* This is strange indeed, and certainly very interesting.

Other amphibians undergo less complete metamorphoses. The continental *Salamander* (fig. 155) for instance, and the Triton (fig. 154) that we call Water-Newt, retain their tail all their life. Some tropical Amphibians are snake-like, and have no limbs.

39. Usefulness of Toads. Their venom. — **1.** The toads do harm only to insects, worms, and snails, of which they devour great numbers. In our country the poor Toads are often cruelly and stupidly destroyed. It will undoubtedly not a little astonish you to hear that great numbers of these useful but disregarded creatures are sent from Europe to Australia*, to help to keep the gardens free from noxious and destructive guests, such as snails, insects, etc.

But if I advise you to spare the toad, I would also bid you avoid touching it. Look at this one (fig. 152) I caught for our lesson, and which I touch only with a pair of tongs. This way of handling it is evidently not at all to its taste, and has set it in wrath. **2.** You can see all over its back, and especially about its neck, a great many little drops of liquid oozing out of its skin. **3.** That is *venom, and is most pernicious.* If a drop of that milky like substance were to be put under the skin of a fowl, it would be sufficient to kill it : you see it is not to be played with.

4. All Amphibians have more or less venom in their skin. If you happened to rub your eyes after handling a frog, you would not fail to feel them smart a good deal.

SUMMARY. — AMPHIBIANS.

1. Metamorphoses (p. 59). — Some **Amphibians**, *aquatic* when young, *aërial* when full grown, undergo changes in form which are called *metamorphoses.*

2. When young they are *Tadpoles;* have a large head, a long

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1. What services do frogs and toads render us? — **2.** How does the toad secrete its venom? — **3.** What effect does this venom produce, when introduced under the skin of a hen? — **4.** Are toads the only amphibians that have venom under their skins?

numerous, some 13,000 species being known to exist. In the *fresh water* of our country are to be found the Carp, Tench, Barbel, Gudgeon, Bream, Roach, Dace, etc., also the ***Pike*** (fig. 163), *Salmon* (fig. 164), ***Trout***, ***Perches***, *Sticklebacks*, ***Eels*** (fig. 158), etc.

Sea fish are much more varied in shape, and also more numerous in species.

1. The *Herrings* pass the greater part of their lives in the deep parts of the northern seas. **2.** When the milting season comes on, they gather together in great *bands or shoals*, of millions and millions, and approach the shores of Great Britain and France, followed in the wake by large fishes, dolphins, and sea birds that come to prey upon them. Man is, however, the great destroyer of the Herring tribe. Whole fleets are laden with the spoil. Fortunately each female lays an immense number of eggs, about 50,000, otherwise their race would soon quite disappear from under the sun.

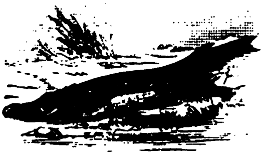

Fig. 163. — Pike. Fresh water fish.

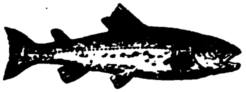

Fig. 164. — Salmon. — Fresh water fish.

3. The *Sardine*, an inhabitant of the Mediterranean sea and the Atlantic, is a sort of small herring that lives in *shoals*, like its bigger relative we have just mentioned.

4. The *Cod* (fig. 165), is a sea fish also, and for its capture immense fisheries, that employ hundreds of vessels, have been organised in the North seas, especially in the waters of Newfoundland *.

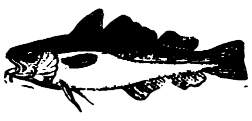

Fig. 165. — Cod. Seafish.

Of the *Flat fish*, the most frequently met with on our coasts are the ***Flounder***, the ***Sole*** (fig. 159), and the ***Turbot***. Some of this group ascend rivers for a pretty considerable distance.

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1. Where does the herring pass the greater part of its life? — **2.** Where *and under what* circumstances do our fishermen meet with it? — **3.** What is the sardine? — **4.** Where have great cod-fisheries been established?

Mackerel (fig. 157), visit our coasts in great numbers during the summer; the *Tunny fish*, which according to John Davy has a temperature higher than that of the water in which it lives, is sometimes 13 to 18 feet long.

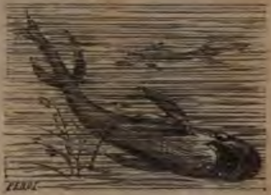

Fig. 166. — Shark sometimes measures 40 feet. Ferocious fish. Mouth under the head.

1. One species of the *Shark* kind (fig. 166), has monopolised all the celebrity of its race, by its great size and its great ferocity. This dreaded sea monster sometimes 40 feet long, swallows almost every thing it meets with, destroys enormous numbers of fishes, and could snap off a man's leg as easily as you could bite through a bit of apple. **2**. For this purpose it is provided with a great mouth situated not at the end of its snout as is the case with other fishes, but *under its head*, and set with several rows of formidable triangular teeth. The gills have five slits, instead of the one existing in ordinary fishes.

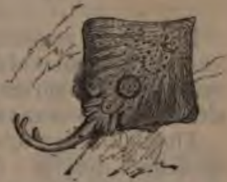

Fig. 167. — Ray. — Mouth under the body.

Suppose you were to flatten out a shark you would have an animal very like a *Skate* (fig. 167).

The *Lamprey* (fig. 168), bears great resemblance to the eel, but it has no side fins. On either side of the neck it has seven gill slits, and its mouth is a sort of circular opening set with sharp teeth, and which it uses as a sucker, thereby fixing itself firmly to no matter what, stones, etc.

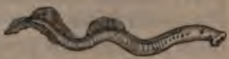

Fig. 168. — Lamprey.

There are a great many other curious fishes we might pass in review, but we must leave sufficient time for the study of other subjects.

SUMMARY. — Fishes.

1. **Fishes** (p. 62) are absolutely *aquatic*. Out of water they inevitably perish.

---

1. Which is the most ferocious fish? — 2. Where is its mouth placed?

There are fish that live in the *sea*, others in *fresh water*. — Certain species *migrate* from the sea into rivers, and others from rivers to the sea.

2. The form of fishes is extremely varied. Some, the most numerous, bear a resemblance to a flattened spindle; others, like the *Eel*, are not unlike the serpent; some are flattened sideways like the *sole*; others otherwise, like the *skate*.

3. All fishes have *gills* by which they breathe. Almost all have fins.

4. The most dangerous of fishes is the *Shark*, which attains at times the length of 40 feet. It is provided with a great mouth, situated not at the point of the snout, but *under* the head, which mouth is armed with several rows of formidable triangular teeth, with which the monster is able to snap off the thigh of a man with the greatest ease.

II — ANNULATES.

1. You all remember the meaning of the word *annulate*. The bodies of the members of this group seem to be composed of a series of **rings** strung together as it were; although those rings are not always very like one another.

The following are the groups into which Annulates have been divided: *Insects*, *Spiders*, *Millepedes*, *Crustaceans*, and *Worms*.

44. Insects. — **2.** First in order we find the **Insects** *that have* **six feet**, like this butterfly. **3.** Their body is, as you can see, composed of three parts (fig. 169), the *head* A, the *thorax* B, and the *abdomen* C. **4.** The head bears two horns or feelers D, properly called *antennæ*, and two large eyes, which seem, if you examine them with a magnifying glass*, to be cut *with facets*, like precious stones (fig. 170). **5.** The six feet are borne by the thorax; and it is the thorax also that bears the four wings of our butterfly, and the two wings of yonder fly (fig. 171). Antennæ, limbs, and wings, and all similar organs, are called *appendages*.

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1. What is the definition of the word *annulata*, that is given to a very important group of insects? — 2. What characteristic is common to the *insect* group? — 3. Into how many parts are the bodies of insects divided? — 4. What name is given to the two feelers? — What peculiarity do their eyes possess? — 5. On what part of the body are the six feet and wings placed?

None of these being found on the abdomen, we therefore say that it has no appendage.

Many insects undergo metamorphoses quite as complicated as those of the frog. You have all had occasion to observe those of the butterfly (fig. 172) **1.** When newly out of the egg, it is a tiny *Caterpillar* A, which grows very rapidly and casts its skin four times. **2.** The fifth time its skin becomes thick and hard, the caterpillar seems to have fallen into a deep sleep, *after* having, in some cases, spun a silky bed called a *cocoon*, in which it shuts itself up. **3.** In this state it takes the name of *Chrysalis*. **4.** At the last, the sixth change of skin, the chrysalis bursts and ushers into sunlight a winged butterfly, C, ready to lay its eggs. **5.** This is what is called a *complete metamorphosis*.

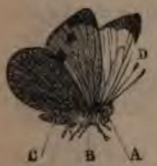

Fig. 169. — Body of an insect (butterfly). A, head. — B, thorax. — C, abdomen. — D, antennæ.

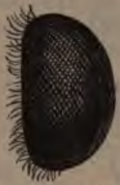

Fig. 170. — Insect's eye, as if cut with facets (greatly magnified).

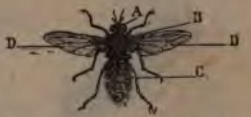

Fig. 171. — The six legs and two wings belong to the thorax. — A, head. — B, thorax.—C, abdomen.—D, wings.

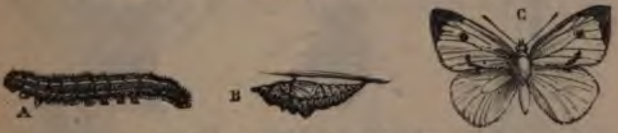

Fig. 172. — Metamorphoses of the Butterfly.
A, Caterpillar. B, Chrysalis. C, Butterfly.

6. *Grasshoppers* also undergo metamorphoses, for the *young ones have no wings when born*, but at each casting of their skin, the wings gradually grow; and after

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1. Under what form does the butterfly come out of its egg? — **2.** What becomes of the caterpillar at its fifth transformation? — **3.** What name is given to it in this state? — **4.** What becomes of the chrysalis after the sixth change? — **5.** What name is given to these different changes? — **6.** What are the metamorphoses of the grasshopper?

the sixth change the insect attains its perfect state without having passed through the deep sleep of the chrysalis, or any such extraordinary change as the butterfly has done. **1**. This is what is called *incomplete* or *partial metamorphosis*. **2**. *Flies* (fig. 173), *beetles*, *fleas* (fig. 174), and *bees* (fig. 175), undergo complete metamorphoses

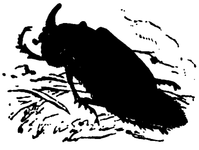

Fig. 173. — Beetle.

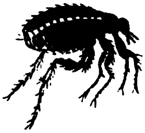

Fig. 174. — Flea (magnified).

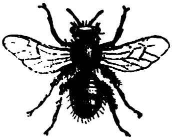

Fig. 175. — Bee.

3. *Dragon flies*, *gnats* (fig. 176), and *bugs* (fig. 177), undergo but partial ones. **4**. The mouth of an insect is not at all constructed like ours or that of any vertebrate: its jaws or mandibles, instead of moving upwards and downwards, are laterally placed, and move from right to left. **5**. Look at this beetle, see its powerful jaws (fig. 178), which enable it to lay hold of and tear to pieces other insects, on which it feeds. This cockchafer (fig. 179) that lives on leaves has much weaker mandibles. **6**. Flies have a short but strong *proboscis* B (fig. 180) well adapted for sucking; fleas and bugs have *sharp* styles C (fig. 181), with which

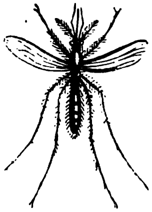

Fig. 176. — Gnat (magnified).

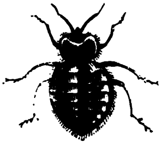

Fig. 177. — Bed bug (magnified).

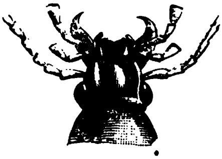

Fig. 178. — Head of beetle (magnified) seen from underneath.

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1. What name is given to these changes? — 2. Name some other insects that pass through a complete metamorphosis. — 3. Mention some *other* insects whose metamorphoses are incomplete. — 4. How do the jaws of articulated animals move? — 5. Give two examples. — 6. What shape has the fly's jaw? the flea's? the bug's? the butterfly?

they pierce the skin in order to suck the blood of their victim; the butterfly has a long *coiled up proboscis* (fig. 182), which it unrolls and plunges into flowers in order to obtain the sweet liquids contained in the perfumed calyx.

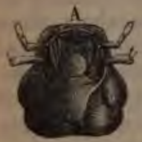

Fig. 179. — Head of Cockchafer (magnified) seen from underneath. A, superior extremity.

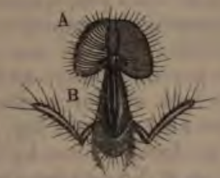

Fig. 180. — Trunk of fly (magnified). — A, sucker. — B, sheath of sucker.

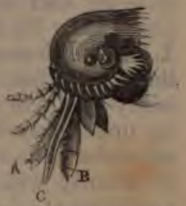

Fig. 181. — Head of a flea (magnified). A, B, sheath of sucker. — C, pointed style.

1. *The group of insects is the most numerous in species of all the animal kingdom; their number amounts to above* **150,000**.

There are very useful species amongst them : such as the *silk-worm*, the *bee*, the *cochineal* insect, etc.; but there are some very noxious ones also, such as *caterpillars*, *cockchafers*, and many others.

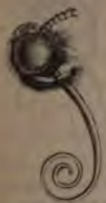

Fig. 182. — Head of butterfly (magnified).

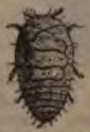

Fig. 183. — Phylloxera without wings (greatly magnified).

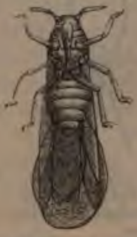

Fig. 184. — Phylloxera with wings (greatly magnified).

The most destructive and terrible of all is a so-called plant louse, a native of America, that came across to France about twenty years ago : it is called the *Phylloxera*. **2**. So

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1. Mention the leading kinds of insects. — 2. What is the phylloxera

tiny is it that one can scarcely discern it with the naked eye. 1. *It lives upon the tenuous roots of the vine, which it sucks and exhausts* so that the much-prized plant pines away for three or four years, and finally perishes. 2. It multiplies with prodigious rapidity, and millions of these tiny but terrible invaders are in a short time ready to leave the parent colony, and wingless travel on underground to look out for a new home. 3. Besides these, there are also winged (fig. 184) members of the family which go forth, borne by the wind to lay their eggs at a distance. 4. No wonder, then, that countless legions of phylloxera have already infested the greater part of the vineyards in the south of France, and that notwithstanding the active warfare directed against them.

45. Spiders. — After the insects we come to **Spiders** (fig. 185). 5. All of these possess **eight feet,** as I have already told you. The head and the thorax are blended into one body, to which are attached the eight feet. They never have wings.

6. The spiders, properly so called, have in their mouth relatively large poison jaws (fig. 186), with which they puncture, benumb and kill the insects on which they prey. Some species in

Fig. 187.—Scorpion, their poison apparatus is at the end of the tail. Length 3 inches.

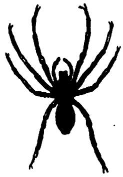

Fig. 185.—Spider, 8 feet, head and thorax blended in one.

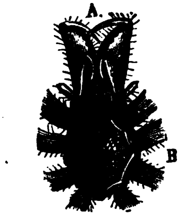

Fig. 186. — A, poison hooks of the spider (magnified). B, thorax seen from underneath, showing where the 8 legs are attached.

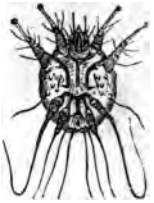

Fig. 188. — Itch insect, a tiny spider, invisible to the naked eye. Seen from underneath.

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1. On what does it live? What effect does it produce? — 2. The phylloxera being so small, why is it so dangerous? — 3. By what circumstance is the phylloxera rendered *still more obnoxious?* — 4. What are the ravages already caused by this insect? — 5. How many feet have spiders? — 6. What is the nature of the hooks that the spider has at its mouth?

America are about the size of my thumb, and are able to seize and suck to death little birds.

1. Most spiders have on the extremity of the abdomen a sort of *spinning apparatus,* from which they draw a very fine but wonderfully strong thread, and with it many species weave artistically complicated webs. **2**. This web the spider stretches out, then lies in wait for the poor heedless insects that may happen to rush into the snare. As soon as the insect is entangled, the spider pounces upon it, benumbs it with a prick of its venomous weapon, and fetters the prisoner with a winding silken thread.

In warm countries, under stones in dry places, are to be found long bodied creatures somewhat akin to spiders. Their antennæ or feelers are terminated by strong pincers : they spin no thread, and their poison apparatus is situated at the tip of their tail, instead of being in the mouth, as is the case with spiders. **3**. These are *Scorpions* (fig. 187). Their sting occasions fever to mankind, and death to small animals.

4. The loathsome disease, known under the name of *Itch*, is caused by *a very small animal* (fig. 188), *a sort of spider scarcely visible to the naked eye, and that furrows under the skin*, producing thereby insufferable itching. **5**. In former times people thought this was caused by impurity of blood, and the poor patients were bled and physicked with greater ardour than success. **6**. It has since been ascertained that the only cause of this disease is the existence under the skin of these minute insects. Sulphur ointment rubbed on the infected parts suffices to dispel the distemper. You see, even in little things, how useful science is, and how important it is to be sufficiently acquainted with one's enemy.

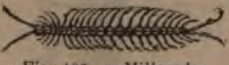
Fig. 189. — Millepeds.

46. Millepeds. — The **Millepeds** and Centipedes, so called with exaggeration, have at least twenty pairs of feet (fig 189). In their case the *head* is distinct from the rest of the body. Properly speaking, their body has

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1. Where is the spinning apparatus of the spider placed? — 2. What does it produce? — 3. Why do spiders spread their webs? — 4. By what animal is the itch produced? — 5. To what cause was the itch formerly attributed? — How was it treated? — 6. How is itch now treated?

neither thorax nor *abdomen*, but simply a series of rings, each of which, according to species, bears one or two pairs of legs.

47. Crustaceans. — All the articulata, with which I have hitherto entertained you, are *aërial* and live upon land. On the contrary, *cray fish* (fig. 190), *lobsters*, *crabs* (fig. 191), and animals akin to them, are almost all aquatic. Because of their crusted skins, they take their name of *crustaceans* (from the Latin *crusta*, a crust). Many insects, for example our dragon-flies, are, like the amphibia, aquatic when young. On the other hand, among crustacea, the land-crabs are largely, and the woodlice wholly, air breathers living on land.

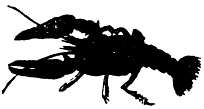

Fig. 190. — Cray fish (Crustacean).

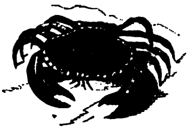

Fig. 191. — Crab (Crustacean).

48. Worms. 1. These animals have no distinct head nor corselet. Contrary to the above-named, no worm-like animals even have jointed legs, but may have, instead of them, either bristles called *setae* or *suckers*, which however serve the same purpose, viz, locomotion.

The *Lumbric* or *earth worm* is of all the best known. See here is one the gardener cut in two when digging in the garden. 2. If you put those two halves in a flower pot, with earth kept constantly moist (fig. 192), *in less than a year you will find two whole worms:* a head will have grown on the half that had but a tail, while a tail will have grown to the half that had none.

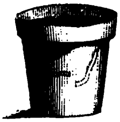

Fig. 192. — In less than a year you will find two entire worms.

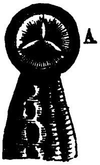

Fig. 193. — Sucker of leech (seen from underneath).

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1. What distinguishes worms from *insects?* — 2. What becomes of an earth-worm when cut in two and placed in a pot of damp soil ?

1. *Leeches* have a sort of *sucker* (fig. 193) by which they fix themselves firmly. The kind used for medical purposes have teeth strong enough to pierce the human skin.

Both worms and leeches are found alike on land and in fresh as well as in salt water. Some worms construct either earthy or stony tubes, in which they live.

2. The *intestinal worms* that live in the body of the greater animals are generally white. Mankind is not exempt from their attacks. The most frequently met with is the *Ascaris lombricoides*, so called on account of its resemblance to the earthworm, colour however excepted. **3.** The *Tænia*, sometimes called *Tape worm*, is by no means rare either. **4.** It looks like a long tape divided into rings or segments (fig. 194), and is sometimes about 20 yards long. **5.** At the pointed end of the worm, one can perceive with the aid of a magnifying glass a very small head A armed with sorts of suckers and hooks. Mankind and flesh-eating animals are subject to having the tænia.

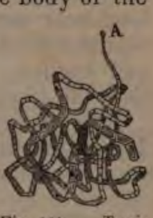

Fig. 194. — Tænia (very much reduced in size). Improperly called *tape worm*. — A, head. — The tænia sometimes are 20 yards long.

The history of these animals is very curious indeed. **6.** Each of the ring-shaped divisions of their body is full of eggs, and is sooner or later expelled. **7.** This expelled division dries up; the eggs it contained, thus liberated, lie scattered about. If subsequently a grazing animal happens to pass by and swallows, along with the grass it eats, some of those eggs, they forthwith begin a new evolution. **8.** No sooner does the egg reach the animal's stomach than it is hatched, giving birth to a tiny creature that manages to pass through the wall of *the intestine*, and chooses an abode in some part of *the body;* once housed there **9.** a sort of ball grows on the extremity of its body, and swelling out, all but hides its head. This

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1. How do leeches fix themselves to the skin? — **2.** What is the common colour of intestinal worms? — **3.** What is the scientific name of the worm called *tapeworm?* — **4.** To what do the *tænia* resemble? What length may they reach? — **5.** By the help of a magnifying glass what can be seen at the pointed end of the worm? — **6.** What becomes of its segments? — **7.** And when cast out, what becomes of them? — **8.** What becomes of one of these eggs, when in the body of a sheep? — **9.** What malady does their presence cause in pigs?

head is exactly similar to that of the tænia. It is those balls, when developed under the skin of a pig, which occasion a well-known malady, called pigs' measles. **1.** The little animal will there and thus remain for any length of time; but were a dog, or even a man, to eat raw or insufficiently cooked (although smoked and salted) pork containing one or more of these globular creatures, the little ball would be digested in his stomach, the head only remaining. In a very short time, however, a segment would add its length to the head, then another and another, and the dog or the poor man is said to have the tænia.

This is certainly a very complicated way of living. **2.** and the history of the tænia should show you *how very essential it is to be careful to eat only wholesome pork, and for further security to have it perfectly cooked, for ordinary curing has not much effect on the little parasite.*

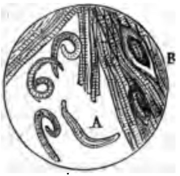

Fig. 195. — A piece of trichinized flesh greatly magnified. At B the little worms are seen buried in the substance of the muscle and at A they are shewn liberated.

In all cases it is prudent to eat well-*cooked meat.* **3.** Some 50 years ago, an almost invisible worm was discovered; this one also lives in pig's flesh, and is called the *trichina* (fig. 195). In Germany and in America it is very common. **4.** When trichinized pork, *imperfectly cooked,* has been eaten, the little creatures which it contains in great numbers, lay eggs in the intestines; when hatched, the young ones disperse all through the body, causing intolerable pain and frequently intense and deathly fever.

SUMMARY. — ANNULATES.

1. The animals comprised in the great group of **Annulates** seem to be formed by a succession of **rings** or segments strung together.

Annulates are divided into *Insects, Spiders, Millepeds, Crustaceans,* and *Worms.*

What may happen to a man who eats of this bacon when insufficiently cooked? — **2.** What conclusions do you draw from this? — 3. What else has lately been discovered in the flesh of pigs or swine? — 4. What happens if this meat is eaten when insufficiently cooked?

2. **Insects** (p. 66). — **Insects** all have *six* feet.

3. Some of them undergo metamorphoses more complicated still than those of the frog.

4. The *Butterfly,* for instance, when newly come out of the egg, is a *caterpillar.* After having several times changed its skin, the caterpillar seems to fall asleep, wraps itself up sometimes in a cocoon and becomes a *chrysalis.* From this chrysalis issues forth a winged butterfly. Such a metamorphosis is said to be *complete.*

5. *Flies*, *Beetles, Fleas*, and *Bees*, undergo complete metamorphoses. *Grasshoppers*, *Dragonflies*, *Gnats*, and *Bugs* have *incomplete* metamorphoses.

6. The group of Insects is the most numerous of all those of the animal kingdom : upwards of **200,000** species are comprised therein.

7. The **Phylloxera** is an insect almost invisible to the naked eye. It lives on the tenuous roots of the *vine,* and sucks them till they are exhausted. And notwithstanding the war waged against them over one million acres of vineyards have already been destroyed on the Continent.

8. **Spiders** (p. 70). — **Spiders** have eight legs; near the mouth venomous hooks exist with which they prick, benumb, and kill the insects on which they prey. — At the extremity of their abdomen is situated a sort of spinning apparatus, from which issues a very fine and silky thread with which they make their web.

9. In the south of Europe and in all warm countries creatures somewhat akin to spiders are found; these creatures are called *scorpions.* Their sting, situated at the tip of their tail, can occasion intense fever.

10. The *itch* is occasioned by a sort of very tiny spider, scarcely visible to the naked eye, which hollows out galleries under the skin, thus giving rise to intolerable itching.

11. **Millepeds** (p. 71). — The **Millepeds**, etc., if they have not so many as a thousand feet, have certainly a great many. Their body is composed of rings.

12. **Crustaceans** (p. 72). — **Crustaceans** (crayfish, crabs, etc.), are almost all aquatic animals. Their skin is crusty, thence their name.

13. **Worms** (p. 72). — If a **worm** be cut in two, and left in moist earth, in less than a year two complete animals will be found : a head will have grown on one half, a tail on the other.

14. *The tape-worm* or *Tænia* looks like a long tape with ring-shaped divisions. Mankind and some animals are often afflicted by the Tapeworm.

15. The *Trichina*, a little worm almost invisible to the naked eye, lives in pigs' flesh. In order to destroy these Trichinæ, the pork must be *carefully and completely cooked.*

III — MOLLUSKS.

49. [1]. The **Mollusks** are, as we have already seen, soft fleshy animals in which no trace of ring-shaped divisions exist, and which in many cases have their bodies enclosed in stony shells.

50. Gasteropods. — These mollusks, having a head and a long creeping foot, are called *belly-footed* or *gasteropodous* animals.

The shell of a *snail* (fig. 196) is a spirally coiled tube which widens out as it nears the mouth; the body of the snail penetrates into the furthest extremity of its shell.

Look at this snail, it is quite at ease; it stretches itself out and pushes forth its head; it also possesses four horns or tentacles, two of which, A, bear minute eyes, and lastly a thick fleshy sort of foot, on which it travels slowly along. If you but touch the creature all this will instantaneously be withdrawn and hidden in the shell.

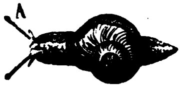

Fig. 196. — Snails. — A, horns terminated by small eyes.

Fig. 197. — Slugs.

Slugs (fig. 197) have, like their cousins, the snails, a head, four horns, and a fleshy foot, but no shell to cover their body. In some cases however a rudimentary sort of shell does exist, but it is hidden under the skin of the back. The snails and the slugs are land animals. Other gasteropods live in fresh water; but the marine species are by far the most numerous, and present a great variety of forms.

51. Acephala (a name which means *head-less*).

The acephales, *Oysters* (fig. 198), *Mussels*, etc., have double shells; they are provided with an upper and an under part called *valve*, hence the name of *bivalves* given to them. These animals have no head, and are aquatic.

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[1] *To what kind of* animals do we give the name mollusks? Give some *examples.*

Oysters are marine* animals, that live in large colonies called *beds*: they are fixed on the rocks, and *cannot move out of their place;* mussels on the contrary can *free* themselves at will. Some live in the sea, and some in fresh water, but they are of different species.

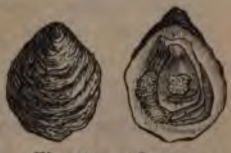

Fig. 198. — Oysters.

1. The interior lining of these molluscans' shells is utilised under the name of *Mother of Pearl;* it is often very beautiful, and many pretty things are made of it.

2. When foreign bodies happen to be introduced between the animal and its shell, a series of shelly caps are formed around them; upon the capture of the animal these are removed, and constitute what are called *pearls*, which are eagerly sought for, and are of great value.

52. Cephalopods. — **3**. There exist in the seas, all over the world, Molluscans that generall yhave no outward shell: they are the *Octopus* (fig. 199), *Cuttlefish*, *Calamary*, etc. The Nautilus, whose pretty shells are often brought home by sailors from the Indian seas, is a cephalopod, rather different from those I have just mentioned. They are strange and hideous creatures, with a large head, two great eyes, and a strong horny beak. Their mouth is surrounded by eight or ten long arms covered with suckers, somewhat like those of the leech, and with which they lay vigorous hold of whatever comes within their reach. When irritated some of them emit a black liquid which darkens and troubles the water around them, thereby permitting flight: this black substance is used for artistic purposes and is called *sepia*.

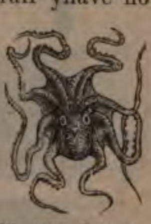

Fig. 199.—Octopus.

These animals often grow to an enormous size, and become dangerous even to man. Some have been known to measure ten yards or more in length, and their arms were almost as long as the rest of their body. Men in fishing boats have sometimes been attacked by these marine monsters.

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1. Where is mother of pearl found? — 2. How are pearls formed? — 3. What is known under the name of cephalopods?

All these creatures are so fashioned that their feet surround the mouth, and they are therefore said to be *head-footed* animals or *cephalopods*.

IV — RADIATES.

53. The animals comprised under the denomination of **Radiates** or **Zoophytes** (plant-animal), are of very diversified shape. Almost all of them live in salt water. 1. The best known and most common amongst them are the *star-fish* (fig. 200), the *echinus* (fig. 201), or *sea-urchin*, the *sea-anemones* (fig. 202), the *medusas* (fig. 203), and the *Polypi*. The body of the star-fish is more or less covered with short *spines*, such as are found to a greater degree in the allied *sea-urchin* (fig. 201).

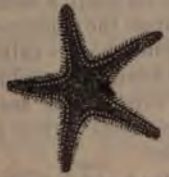
Fig. 200. — Star-fish.

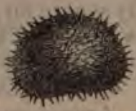
Fig. 201. — Echinus or Sea-Urchin.

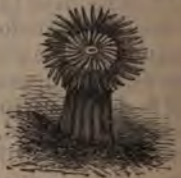
Fig. 202. — Sea-Anemone.

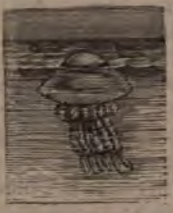
Fig. 203. — Medusa.

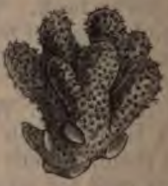
Fig. 204. — Agglomeration of polypi.

The *sea-anemones* (fig. 202) are widely different in organisation, their bodies are quite soft and flabby, and they have no such spines. They are *mostly* of fair size

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1. Which are the best known radiates?

and *live singly*, but *some* are very small and *form great colonies*, which are united together by a tough investment, such for example are the « Dead men's fingers » of the French coast. The investments of others, called *polypi*, form enormous stony masses called *corals* (fig. 204), and in the southern seas whole islands of this substance are still to be found (fig. 205).

The *jelly-fishes* or *medusæ* (fig. 203) somewhat resemble the anemones in their structure; they are free swimmers however.

We must not omit to mention the Sponges. Here is a sponge prepared for use. **1**. It has certainly but little likeness to an animal. Yet it was one. **2**. Only when it was a living being, all those solid though elastic parts were enveloped in a living substance (fig. 206). **3**. *What you see here, is, in fact, but the skeleton of the sponge.*

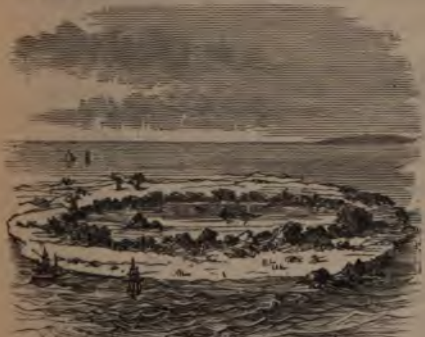

Fig. 205. — Coral Isle polypi.

Fig. 206. — Sponge. The sponge used in commerce is only the skeleton of the animal.

54. **Infusoria**. — I will now tell you something about some marvellous creatures most frequently found in decaying animal and vegetable matter. The majority of them are known as *Infusoria*, but there are others also which are wonderfully small, yet of no little importance. Look attentively at this glass of water, in which

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1. What is a sponge? — 2. When the sponge was alive, what did it contain more than we generally see in a sponge prepared for use? — 3. What then is the sponge that is used in commerce?

I have steeped some bits of old hay. Hold it up between you and the light so as to see very distinctly all it contains. You perceive little mites of things moving in the water (fig. 207). The magnifying glass* will allow you to distinguish them more easily; but a microscope* would be necessary to see them distinctly. **1**. Well, these all but imperceptible specks, *are little animals that live there in myriads;* there are in the glass, tiny creatures of all sorts of shapes. Some are so very small that only the highest magnifiying powers can disclose their presence; thousands exist in a drop of water. **2**. But where have all these tiny beings come from? That puzzles you! They have come from the hay.

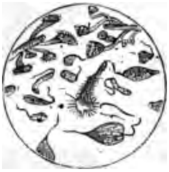

Fig. 207. — Infusoria (invisible to the naked eye) contained in a drop of stagnant water.

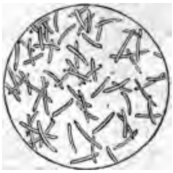

Fig. 208. — Bacteria. Invisible to the naked eye.

3. And how were they there? They were there *dried up, or under the form of eggs.* **4**. There exist creatures akin to those in the almost imperceptible moss on the house tops: quite dried up during the summer time, if examined with the microscope, they look like little grains of green sand. **5**. But if a drop of water fall upon them they unroll their folds, and immediately set out to seek for their living. **6**. When the water has disappeared or evaporated, they become inert as before, waiting for another shower. These are very curious creatures, are they not? And they show you that the most interesting and curious creatures are not always the largest. We will find a new proof of this when we come to study microscopic vegetation.

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1. What is to be seen in a drop of water in which some blades of old hay have been infused? — 2. Whence come these infusoria? — 3. In what condition were they previously? — 4. Where are others to be found? — 5. Under what influence do they unroll themselves? — 6. What becomes of them if the water evaporates?

SUMMARY. — MOLLUSKS AND RADIATES.

1. **Mollusks** (p. 76). — The **Molluscan** group comprises snails, slugs, oysters, mussels, cuttlefish and their allies.

2. *Mother of Pearl* is obtained from the inner layer of the shell of divers molluscans.

3. In some oysters, isolated bits of mother of pearl are formed; they take the shape of tiny and beautiful balls : these are *pearls*.

4. Under the title of *Radiates* a great series of groups is sometimes classed, owing to the fact that their bodies are produced into a series of *rays around a central mouth*. Chief among them are the *sea-stars*, the *sea-anemones*, the *jelly-fishes*, and the *Polypi*. Whole islands are sometimes formed by the agglomerations of these little creatures.

5. The **Sponges** we use are a sort of skeleton, formerly enveloped in a living substance.

6. With a microscope one can distinguish in a drop of water in which some old hay has been steeped, thousands of tiny animals of infinitely varied shapes. These are **Infusoria**.

7. They existed in a dried state in the hay; in the water they become active and move about.

SUBJECTS FOR COMPOSITION.

1st composition (p. 6 to 14). — Differences between animals, plants, and minerals. — Vertebrates and invertebrates. — The four great divisions of the animal kingdom.

2nd composition (p. 15 to 18).—What characterises vertebrates? — Warm-blooded and cold-blooded animals. — Characters of Mammalia, of Reptiles, of Amphibians, of Fishes.

3rd composition (p. 17). — Aërial animals, aquatic animals. — Amphibians.

4th composition (p. 23). — What shows that a bat is not a bird?

5th composition (p. 25 to 26).—The paw of the cat. —Its teeth. — Animals of the cat kind.

6th composition (p. 33). — What is *ruminating* or chewing the cud? — The principal ruminants. — Services rendered by some of them.

7th composition (p. 40). — What shows that a whale is no a fish.

8th composition (p. 45). — General characters of birds. — What is there in an egg? — How are eggs hatched? — Artificial incubation.

9th composition (p. 55 to 57). — What characterises reptiles? — The three groups of reptiles. — What happens to lizards that have lost their tails.

10th composition (p. 57). — Venomous serpents. — Tell what you know of a venomous serpent that inhabits our country. — Where is the poison formed? — Mention serpents whose venom is almost immediately mortal. — Non-venomous serpents. — How those can be dangerous? — Are our snakes dangerous?

11th composition (p. 59). — Metamorphoses of the frog. — By what organs does the Tadpole breathe? by what organs does the frog breathe? — The venom of frogs and toads. — Services rendered by toads.

12th composition (p. 62). — The various forms of fishes. — Give examples. — Of what use are the gills?

13th composition (p. 66). — What is the origin of the word *annulate*? — Principal divisions. — Different kinds of mandibles met with amongst insects. — The number of legs they possess.

14th composition (p. 69). — The Phylloxera.

15th composition (p. 70). — How many legs has a spider? — How do spiders kill flies? — The spider-like creature that occasions *itch*.

16th composition (p. 72). — What happens to a worm that has been cut in two? — The development of the Tænia or Tapeworm. — The trichina of the pig.

17th composition (p. 80). — What is to be seen in a drop of marsh water?

II — PLANTS.

I. — Structure of our Trees.

53. Diversity in the shape and size of Plants. — You have all observed I am sure the great differences that exist in form and size among the divers members of the **Vegetable** kingdom, or **plants**, as they are generally called. An oak, a rose bush, a blade of grass are all three of very different dimensions. To express this we say, there are *trees* (fig. 1), *shrubs* (fig. 2), and *herbs* (fig. 3).

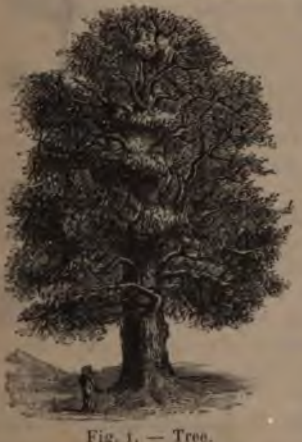


Fig. 1. — Tree.

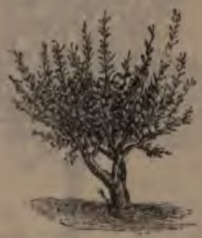


Fig. 2. — Shrub.

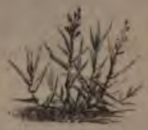


Fig. 3. — Herbs.

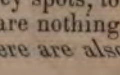
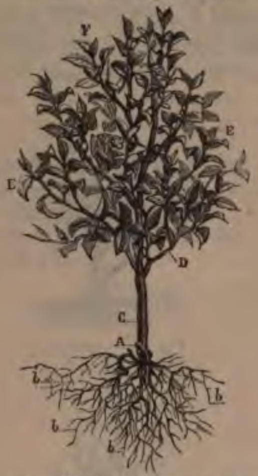


Fig. 4. Mushroom.

All these plants are clad in green, and we shall hereafter see that this colouring is of very great importance. You must know however *that there exist plants that are not green : mushrooms* (fig. 4) for instance are red, or brown, or white ; the yellowish brownish grey spots, to be seen on the trunks of trees or on walls, are nothing else than tiny plants called *lichens*. There are also nnumerable plants which are only clearly visible under our microscopes.

56. The different parts of a plant. — But let us leave for the time being these exceptional plants, and study attentively a common tree.

See here, in a waste corner of the garden, is a young pear tree that has sprung up of itself, as gardeners say. I shall pull it up, so that we may examine it together. **1**. All of you know the different parts of a tree:



g. 5. — Wild pear tree. — A, root. — *b,b,b,b.* — C, trunk. — D, primary branches. — E, secondary branches. F, branch of the third order.

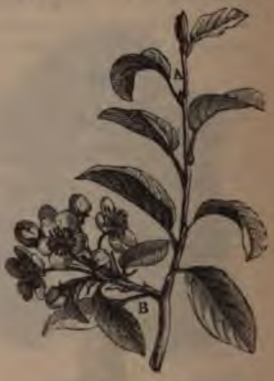


Fig. 6. — Each leaf bears a *bud* A at *its axilla*. — This bud will become a *branch*. — Certain branches B terminate in a *bud*, which will become a flower, and afterwards the fruit.

1 the **root** A (fig. 5), which is hidden under ground, and whose ramifications are called the lateral roots, *bbbb*; 2 the **stem** or *trunk* C. that rises up almost vertically; 3 the **branches**, divided into *primary branches* D, starting directly from the stem, *secondary branches* E, taking origin from the preceding ones; then branches of *third order* F, that spring in their turn from the *secondary* branches, and so on; 4 the **leaves**.

---

1. What are the different parts of a common tree?

Let us now examine certain parts, closely. **1**. Above the stalk of each leaf, just in the angle A (fig. 6), it forms with the stem, or with the branch on which it grows, you see a small **bud**. **2**. *This bud will grow forth and give rise to a new branch.* **3**. *All the branches spring thus from what is called the* **axilla** *of a leaf, and each leaf bears a bud at its axilla.*

4. You may observe that there are some branches B, usually shorter than others, and which *instead of elongating*, remain short and terminate in a flower **bud**. **5**. These buds will become **flowers**, and these flowers will pass away and give place to **fruit**, pears in the present case.

57. The stem. — Let us first take the **trunk** (fig. 7), and cut it across. It is composed as you can see of three distinct parts. **6**. In the centre is the **pith** A, white and soft; then comes the **wood** B, which is hard; lastly all around you can recognise the bark C, which is green and tender, and which you can pull off in strips.

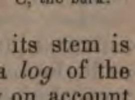


Fig. 7. — The trunk.
A, the pith.
B, the wood.
C, the bark.

This tree we are now examining is a very young one, it sprang up but last year from the roots of an old pear tree that perished by the severe cold of the winter; its stem is quite slender. But I have here beside me a *log* of the old tree (fig. 8) which I kept as a curiosity on account of its great age. We will compare it with the young stem.

The first observation to be made, and a most obvious one you must admit it to be, is, that the old trunk is much larger than the young stem, the diameter * of the former measuring about forty inches: **7**. strange to say, the *area occupied by pith in the old trunk is no greater than in the young stem.* This astonishes you, I have no doubt, yet it is always so. In no case whatever does *the pith grow bigger as the tree grows older.* As for the **bark** C, it is no longer green and smooth, but has

---

1. What is to be seen at the *axilla* of each leaf? — 2. What will arise from the bud? — 3. Where do all the branches spring from? — 4. Have all the branches the same characters? — 5. What become o these buds? — 6. If the trunk be cut across what three parts are discernible? — 7. What is to be remarked about the pith of an old tree?

become grey, rugged and much thicker. 1. The principal difference however is in the bulk of the *wood* B, for it alone constitutes almost the whole stem, or trunk as people say, when speaking about the stem of an old tree.

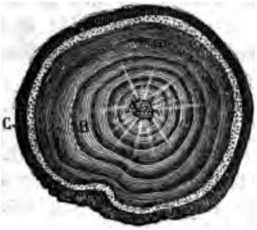


Fig. 8. — Transversal section of the stem of an old pear tree. — A, pith, which does not increase with age. — B, wood with circles fitting into each other, each circle marks a year. — C, the bark.

Here is a slice of the old trunk which I have had polished. 2. *Do you see those* **rings** *all fitting exactly into one another?* George, will you count them? — There are about 65, Sir. — Why do you say about 65? — 3. Because *the rings, very easily counted near the pith, are so closely pressed together near the bark that I can scarcely distinguish them.* How does this happen? — Follow my explanation, and you will easily understand why this happens. 4. *Each of these circles marks* **one** period of growth of the wood, and generally, one **year** *of the life of the tree* (this one then would be about 65 years of age). Every year, the tree grows thicker; you understand of course, that this growth can only take place outwardly, for were the new layer of wood to be formed inside the tree, near the pith, all the old wood, being hard, would inevitably be shivered and rent. The new wood grows between the old wood and the bark. Each of the circles you see corresponds to a yearly layer of wood.

Now, when the tree was young it grew much faster that in its old age; just as children do; for you grew much more rapidly between four and five, than you will grow from 14 to 15. This is why the *transverse diameter of the rings is less as they go further from the centre* of the stem, that is to say, are of more recent formation.

Are any other distinctions made between the divers parts of the wood itself? You should know, Paul, your

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1. Which part of the trunk of a tree develops the most with age? — 2. What is to be seen on attentively examining a slice of wood. — 3. Can these rings be easily counted? — 4. What does each of these circles indicate?

father being a carpenter. — Can you tell me? — **1.** Yes, Sir, there is the **sap wood**, A (fig. 9), which is soft, and the **core** B, which is hard, and is found under or within the sap wood. — Quite right; *the core is harder because it is older, and a greater quantity of solid matter has been deposited there, during a longer period of time*, consequently it will give more heat and leave a greater quantity of cinders, if used as fuel.

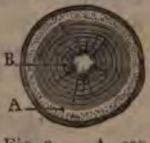

Fig. 9. — A, sap wood; B, the core.

58. The root. — So much for the *structure** of the stem. That of the **root** is similar. There is so little difference between the roots and the stem, that in some cases, as in that of the lime tree, the acacia, the chesnut tree for instance, when a part of the root is laid bare, it becomes, if so left, for any considerable length of time, quite like the stem as far as appearance is concerned, and may even give rise to branches.

59. Branches. — The way in which the branches stand related to the stems is exceedingly varied. Look at the *fir tree* (fig. 10). It gives off at regular intervals horizontally* directed branches; see, on the contrary, this *plum* tree (fig. 11), it branches out in all directions, so that one can scarce follow the main stem.

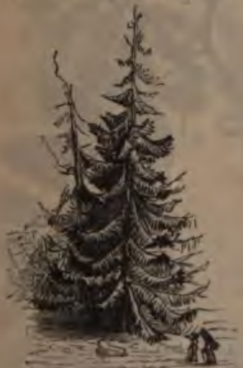

Fig. 10. — Horizontal branches of the fir tree.

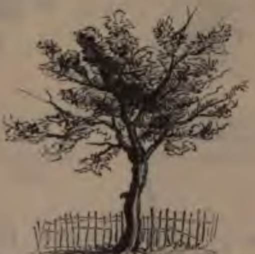

Fig. 11. — Plum tree, branches out in all directions.

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1. What else may be observed of the different parts of the wood?

1. Still, whatever aspect the tree may have, *the stem is always thicker at the lower parts than at the higher*. It tapers gradually, and terminates almost in a point. This is the case, at least, with all the trees of our country.

60. Leaves. — Let us consider the **leaves** now. **2**. Those of our pear tree have stalks A (fig. 12), or to use a more scientific expression, have each a **petiole**. **3**. The petiole supports an outspread green part, which

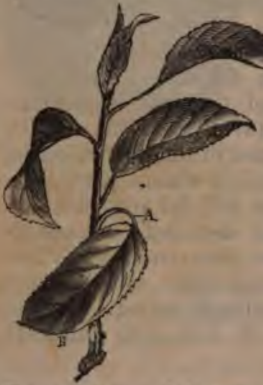

Fig. 12. — Leaves of the pear-tree.
A, petiole.
B, blade or lamina.

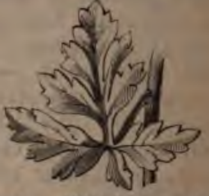

Fig. 13. — Wild Geranium leaf, blade divided.

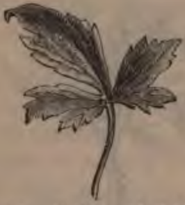

Fig. 14. — Butter cup leaf, blade completely divided.

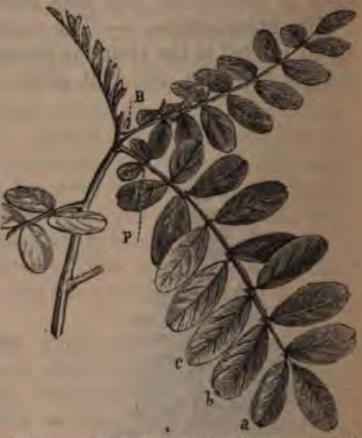

Fig. 15. — Acacia leaf. Blade with complicated divisions. — *a*, *b*, *c*, lobes of the leaf or leaflets. — B, bud. — P, petiole of the leaf.

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1. What general observation may be made regarding the trunks of *trees in our own country*? — **2**. What is the scientific name for the stem of a leaf? — **3**. What name is given to the green part?

is the leaf properly so called : the *blade* or *lamina*. This blade is the most important part of the leaf, and many plants have leaves without stalks. **1**. The leaf of the pear tree has a *simple* blade, whilst that of the wild geranium (fig. 13) is *divided* into several parts. The divisions are *complete* in this buttercup leaf (fig. 14) and *extremely complicated* in the leaf of the acacia (fig. 15). I think I heard Henry whisper that each of these green lobes *a*, *b*, *c*, is by itself a whole leaf. I say he is mistaken. Can any one tell which of us is in the right, and why? Nobody? **2**. Do you not remember I already told you that, *at the axil of each leaf a little bud was to be found*, and you see in this case one only exists, B; and it is situated at the axil of the whole leaf. **3**. Besides if those big petioles were small branches, they would not fall in autumn, and you know that they fall, as all leaves do.

The flowers. — And now to the **flowers**. The first things that meet our eye in our pear blossom (fig. 16), are those five little outspread white leaves A, B, C, D, E. **4**. They are called **petals**. **5**. If we now look at the underside of the flower (fig. 17), we shall see five other leaves F, G, H, I, J, much smaller than the first and that have remained green, those are called

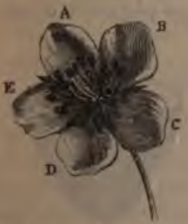

Fig. 16. — A, B, C, D, E, petals. — These taken together form the *corolla*.

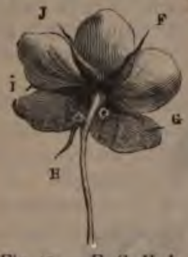

Fig. 17. — F, G, H, I, J, sepals. — The aggregate of these sepals forms the *calyx*.

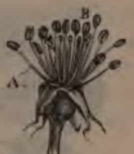

Fig. 18. — A, *stamens*. — B, yellow anthers bearing the *pollen*.

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1. Is the blade always the same shape? — 2. What proves that the lobes in the leaves of the acacia tree are not leaves? — 3. Give another proof. — 4. What name is given to the five little white leaves which form the blossom of the pear tree? — 5. What name is given to the five little green leaves that are found under the flower?

sepals. **1**. In the centre of the flower (fig. 18) there are a number of little things like bristles, A, each finished off by a tiny yellow ball, B : these are the ***stamens***; they owe their yellow colour to a sort of very fine dust, that botanists call **pollen**. You are all aware of the existence of this yellow dust: last year, you remember, I was obliged to punish James, who had so besmeared his face with pollen that he set the whole school laughing.

We will now pluck off the sepals, petals and stamens : **2**. I must not, however, omit to mention that the aggregate of the petals is called the **corolla** (fig. 16), whilst **calyx** (fig. 17) is the name given to that of the sepals. **3**. We have reduced our pear blossom to a little ball, A (fig. 19), surmounted by five minute stalks, B. **4**. This ball is called **ovary** or seed vessel, the little stalks are the **styles**, and the ovary and the styles, taken as a whole, form what is called the **pistil**.

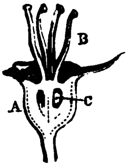

Fig. 19. A, ovary becomes the *fruit*. — B, styles. — A and B, taken together form the pistil. — C, ovules (or white specks) which become *pips or seeds*.

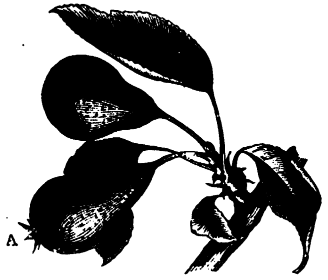

Fig. 20. —A, Remains of the disappeared styles.

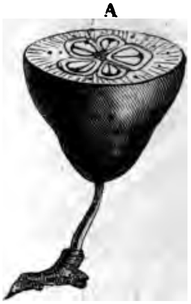

Fig. 21. — A, pips or seeds.

62. Fruit. — A very little thing indeed is the ovary; it will, however, grow big, if spared, when once

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1. What name is given to the little bristles in the centre of the flower? — How do the stamens terminate? — To what is the yellow colour due? — 2. What name is given to the *petals? to the sepals?* — 3. What remains when the sepals, petals and stamens have been taken away? — 4. What name is given to this little ball? to the stalks? to the ovary and styles together?

the calyx, the corolla, and the stamens have fallen away. **1**. It will swell out and become filled with juice, at first sour but afterwards sweet; it will, in short, become a *pear* : the **fruit**. You can easily recognise the ovary, after its transformation into a pear, for on the summit A of the fruit (fig. 20), you still find vestiges of the parts that have disappeared; they have made a little hollow, right opposite the stalk.

2. In this fruit, you know, there are *seeds* A (fig. 21), loosely hung in small cells. If we cut across the ovary of our pear blossom (fig. 19), we shall see in it very small white specks, C. **3**. Those specks, which we can pick out with a pin, are called **ovules**, that is to say, *little eggs*. Those tiny things, in the course of time, will become the *seeds* (fig. 21).

4. *So a* **calyx**, a **corolla**, and **stamens** *destined to disappear, an* **ovary** *which is to become a* **fruit**, and **ovules** *that are to become* **seeds**, *such is the composition of a* **pear** *blossom.*

65. Imperfect flowers — A flower such as that of the pear tree is said to be *complete*. There are also *incomplete ones*. In some, the calyx is wanting, in others the corolla, sometimes even both, but this is of no great importance.

I see this astonishes you, and that in your opinion the most important parts of the flower are the beautiful petals so often decked in gay and brilliant colours. But this is not the case. **5**. *The really important parts of the flower are the* **stamens** *and the* **ovary**; I should even say the **grains of pollen** and the **ovules**.

What proves this is that many flowers have neither calyx nor corolla. The flower of the Hazel nut, for example, and yet the Hazel tree (fig. 22), bears fruit as you well know, and that is the principal end of its existence. Another proof is, that you may pluck away the petals and sepals of a perfect flower, and by no means hinder the development of the fruit, provided the stamens and the pistil remain uninjured. **6**. *But if you pick off*

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1. What becomes of that little ball? — **2**. What is to be found in the fruit? — **3**. What will these tiny specks become in the course of time? — **4**. What then becomes of each part of the pear blossom? — **5**. Which is the most important part of the flower? — **6**. What happens if you destroy the stamens of a flower?

the stamens, the ovary will not develop, or as horticulturists say, the fruit will not *knot*.

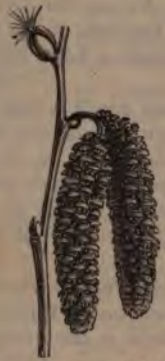

Fig. 22. — Flowers of the hazel nut. — They have neither calyx nor corolla.

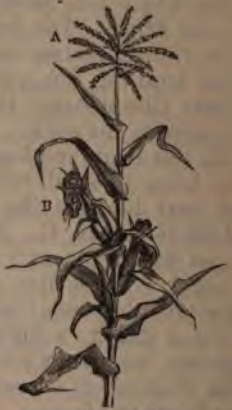

Fig. 23. — Flower of the maize or Indian corn. — A, flowers with stamens. B, flowers with pistils.

Fig. 24. — All the Weeping Willows of Europe have flowers with pistils (those with stamens are in Asia).

1. This is not all; there are also flowers that do not possess both *stamens* and *pistils :* some bear stamens, while others bear pistils. **2**. *Such flowers if kept too far apart from one another remain barren*, that is to say, produce *no fruit*. **3**. Sometimes both kinds of flowers grow upon the *same plant*, as is the case with the melon, the birch, the walnut tree, the maize or Indian corn (fig. 23). **4**. Sometimes they each grow *upon a different plant;* this is the case with hops, hemp,

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1. Do all flowers possess both stamens and pistils? — 2. What happens if these flowers are kept far apart from each other? — 3. Where are the two kinds of flowers found in the melon, birch, walnut tree, and maize? — 4. In hops, hemp and willow?

willows, etc.; if these plants are not near enough to each other, they will never bear fruit. **1.** See there, on the water's edge, that beautiful weeping willow (fig. 24); it is a native of Asia; and as only one kind has been brought to this country, the one bearing pistils, nobody, in our part of the world, ever saw any of its seed, and all the trees of the kind, that decorate our gardens, have come from *slips**, and bear flowers with ovaries that remain unfruitful.

64. Seed. — We will now return to our pear blossom or rather to its fruit. **2.** It contains *pips*, or *seeds*, which if put in the ground *will give birth to a pear tree similar to the tree that bore it*. Let us examine carefully one of these seeds. **3.** We first meet with a *covering* or *skin*, and within it, the seed properly so called. As the seed of the pear tree is too small to allow us to see its details with sufficient accuracy, we will take a larger one, that of an almond tree for instance.

4. The skin once removed, we find two fleshy* bodies, which are very savoury (C, C′ fig. 25), and constitute almost the whole bulk of the almond. **5.** Botanists* have given them the name of *seed-leaves* or *cotyledons:* I do not like to give you those big ugly Greek words, but very often it is impossible to avoid them.

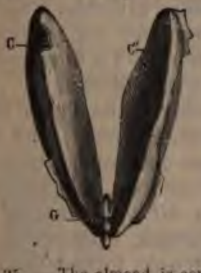

Fig. 25. — The almond is composed of two large fleshy bodies C, C′ called *cotyledons*. — G, is a plant in miniature.

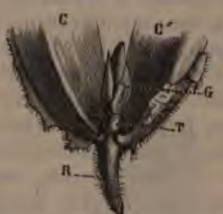

Fig. 26. — CC′, cotyledons. — R, radicle. — G, plumule.

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1. What is remarkable about the weeping-willow?—**2.** What becomes of pips and seeds when put into the ground? —**3.** What is to be observed in the seed of a pear? —

4. When the skin of an almond is taken away, what is found? — **5.** What name do botanists give these two fleshy bodies?

See I have carefully separated those cotyledons; do you perceive, at the pointed end of the seed, a little body G? **1.** Look at it closely, very closely; *it is really a miniature plant.* **2.** One can distinguish, without great difficulty, a tiny root R or *radicle* (fig. 26), a minute stalk T, and on the top, a very small bud. And the cotyledons C, C′, of what use are they? **3.** They are simply the two first leaves of the plant. **4.** Were we to put the little fruit (the almond), in the earth, the radicle R would become the root T, and the plumule G would grow up to form the plant. As for the cotyledons, their history is more complicated, and we will hereafter see what becomes of them when we study *germination**.

II. — Structure of Palm trees.

65. We have, in a general way, gone over the history of our pear tree and its fruit. I now wish to examine with you another tree, one altogether different from the foregoing, a *Palm-tree.* Unfortunately none grow in this country excepting in hot houses*. To find one we should be obliged to go to some warm climate.

You may ask : but why then choose the Palm tree? There are in this country many other trees. The oak, elm, poplar, etc. Quite true, dear children; but *what I have told you concerning the pear tree, is applicable to all those trees, nay even to all the trees of our country.* **5.** All these have a **trunk** *thicker at the base than at the top*, a *conical** trunk, to use the geometrical expression; all have **a bark** and **wood** harder in the centre, and *rings* fitting into one another, and **pith**; the stems of all of them bear **branches or twigs**, which come from **buds** situated at the axilla of the **leaves**; all of them also bear *seeds* that have **two cotyledons.**

But a palm tree is altogether different, and it is for that reason I find it necessary to tell you about it. For-

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1. What is to be seen at the pointed end of the seed? — 2. What do you perceive there? — 3. What are *the two cotyledons*?—4. What would happen if we were to put the whole fruit in the ground? — **5. Repeat the general characteristics of the trees of our country.**

tunately I have been able to procure some good engravings that will help you to follow my descriptions.

66. General aspect. — Observe in the first place the general aspect of the tree (fig. 27); how different it is from those of our forests. **1.** *No branches are to be seen along the trunk*, and on the top A only, we find a tuft of *leaves* long, strong, and stiff. **2.** *The trunk* B *itself is from* **top to bottom of equal dimensions**, it is *cylindrical**, not *conical**. From the top, beneath the leaves, great bunches of flowers hang down.

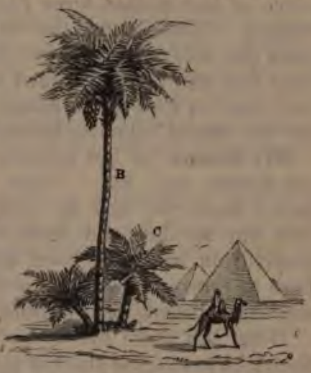

Fig. 27. — Palm tree. — Trunk from top to bottom of the same dimension (cylindrical).

This palm tree is, as you may judge by comparing it with the Arab passing on camelback, about 45 feet high. **3.** It is a tall tree; but just near it is a very young one C, not above 9 feet high, although its trunk is *as thick as that of its elder brother;* strange to say, however *tall it may grow, it never will be thicker* than at present. This then is another great

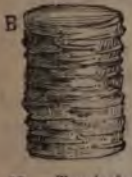

Fig. 28. — Trunk of palm tree. — The scars indicate the place where the leaves have fallen off.

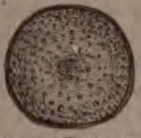

Fig. 29. — Transversal cut of the trunk of a palm tree. — No pith, no circles of wood fitting into each other, no bark.

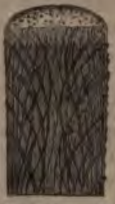

Fig. 30. — Longitudina cut of the trunk of a palm tree. Showing the hard black filaments which give strength to the trunk.

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1. What difference exists in the branches of the palm tree? — 2. In the trunk? — 3. What other great difference is there between a palm tree, and our trees?

difference between the palm tree and our oaks, elms, and apple trees, etc.

Look also at the trunk of the palm tree (fig. 28), you see upon it a series of regular scars. **1.** They mark *the place of leaves that have fallen off;* the highest alone remain. These form the luxuriant tuft which constitutes the sole ornament of palm trees. **2.** These trees have but **one bud or shoot** *situated on the top of the tree, and at that point alone the plant grows.* There are no lateral* shoots, hence no branches.

67. Stem. — Let us now examine this bit of stem cut across (fig. 29). What a strange texture its parts have! Here we find no pith, no rings of wood fitting into one another, no bark. **3.** Instead of the regular disposition we have been accustomed to see, we have here a *spongy mass, in which are seen an immense number of hard black spots, irregularly disposed.*

What can these black spots be? In order to ascertain this I have cut the stem of the palm tree, not across, but lengthwise, through the middle (fig. 30). This shows us, running through the spongy[1] mass (which more or less resembles the pith of our trees), hard black fibres that appeared as black spots awhile ago in the transverse* section we examined. These fibres have a very irregular direction, and seem, at first sight, to wander through the soft mass, which they consolidate. **4.** If closely looked at however, one will observe that they all come from the leaves, run down into the interior of the stem, and thence come back to the surface, where they disappear. **5.** *These threads or fibres are nothing else than the wood of the palm tree, disposed as you see in a very peculiar fashion.* The number of fibres is considerable enough to give the stem sufficient resistance to admit of its being used as timber.

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1. What is the cause of the scars that may be observed on a palm tree? — 2. How many buds are there in the palm tree? — Where is this single bud situated? — 3. What is found in the palm tree instead of the pith, and the rings of wood fitting into each other? — 4. What direction do the fibres take, that we see running through the interior of a palm tree? — 5. What are these fibres?

III. — Dicotyledonous and Monocotyledonous Plants.

68. There are then, between a palm tree and a poplar for instance, wide differences in appearance and in structure. **1.** Moreover, whilst the seed of the poplar and that of other trees of similar construction, have, as we have already learned, **two cotyledons**, the seed of the palm tree and that of all plants of like structure have but **one cotyledon.**

2. It is then quite natural to divide the vegetable kingdom in **monocotyledonous** (from the Greek *monos*, which means *one*) and **dicotyledonous** plants (from the Greek *di*, which means *two*).

In both groups there are both trees and shrubs.

IV. — Duration of the life of Plants.

69. Annual, biennial, perennial plants. — The length of the life of plants is extremely variable.

3. There are some, which in the course of a single year shoot up in spring, grow stems and leaves, give flowers, fruit and seed, and then perish at the end of the warm season. Such are *annual* plants.

4. Others *vegetate* during the first year, that is to say, they bear only leaves; they live through the winter. **5.** The second year only, they flower and fructify, * then they die. Such are *biennial* plants.

6. Annual and biennial plants have but one *inflorescence* or *flowering*, and one *fructification**.

7. Plants are called *perennial* when they flower several times in the course of several years.

In some *the roots alone are perennial*, such as the dahlia. Every year, the knotted root or *tubercle*

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1. What fundamental difference is there between the seed of a palm tree and one of our own trees? — **2.** To what great division do palm trees belong? — **3.** What is to be observed in annual plants? — **4.** What takes place in biennial plants during the first year? — **5.** During the second year? — **6.** In what do annuals and biennials agree as regards their flowering? — Their fructification? — **7.** What are perennial plants?

shoots forth beautiful soft stalks that bear flowers, and die in the autumn : **1.** such is the case with asparagus, hops, etc. These plants have perennial roots and annual stalks.

2. The *real perennials are* the *trees* and *shrubs*. They grow larger every year; but none of their aërial* parts die, and year after year new flowers and new fruit cover their young branches.

V. — Classification of Plants.

70. I will now speak to you about the *classification of plants*. This is perhaps more difficult than that of animals, because plants resemble each other more closely than animals do. Everybody is able to distinguish insects from birds, and amongst insects, flies from butterflies : but it is not so easy to draw lines of demarcation in the vegetable kingdom.

Paul, suppose I were to task you with this classification how would you set to work? —Why, Sir, I should begin by dividing them into trees, shrubs, and herbs. —Well, that idea has come uppermost to many people; but see how many difficulties rise before you. Pray what limits could you find between the three classes? Where does the group of shrubs end, and that of trees begin; and when does a plant merit the name of a shrub instead of being numbered amongst herbs? Are hazel nuts found on a tree or on a shrub? Are furze shrubs or herbs? The distinctions are not sufficiently definite. What do you say, George?

Sir, I think I should class plants as annuals*, biennials*, perennials*, by roots, and the true perennials, as you did a little while ago. — This is certainly a better plan. But is not meadow grass very like corn? Yet corn is annual, whilst meadow grass is perennial : meadow grass and corn would then come under two different categories. More than that, the oats we cultivate are annuals, whilst the wild oats that grow along the roadsides are perennials. Here again are two

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1. Some plants are perennial only *in the roots* ; what takes place regarding these plants? — 2. Which are the typical perennials?

yellow *buttercups* I gathered side by side, one is an annual, the other a pernicious perennial weed almost impossible to destroy. You see this system is far from being perfect either.

71. Importance of the characters of Flowers. — **1**. After long research, botanists* have come to the conclusion, that the best divisions are those drawn from the structure of the *flowers*, the *fruit*, the *seeds;* in a word, all that tends to **perpetuate the species** of the plant.

This conclusion ought not to astonish you, since you already know that the form and structure of the stems of trees whose seeds have but one cotyledon, widely differ from those of trees whose seeds have two cotyledons.

Thus a series of great groups has been constituted, as bringing together under a common head plants often very different in outward appearances, but *bearing flowers, having great similitude to one another.*

72. The Leguminosæ. — I have no doubt you all know the vetch, the lucern, the broom, the furze, the lentil, the clover grass, the pea, the bean, the kidney-vetch, the laburnum, the acacia. Some amongst these plants are simple herbs, others are shrubs, others trees; there are in the number annuals, biennials, perennials; some creep on the ground, some climb, whilst other stand firm and erect; some have soft leaves, some prickly ones. But if we examine the *flowers* of all these plants (the fruit and seed also), we shall see that they are all formed in the same manner, or very nearly; so that if we trace the history of any one of these flowers, what we say concerning it will be applicable to each and all of them; for they differ but little except in size and colour.

Let us take for example a blossom of the common broom (fig. 31), that grows on the road side and displays at this season thousands of bright yellow flowers.

2. You find at first some difficulty in distinguishing the *sepals* D, which are as it were soldered together, the five points only being free. Inside, is the *corolla* with its five *petals;* and very unlike one another they are.

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1. By what characteristics have botanists established a vegetable classification? — 2. What aspect do the sepals of the common broom present?

1. Here is one A, much larger than the others, which rises almost erect; beside it are two smaller ones, one BB, on each side; lastly, the two remaining ones, C, are united as it were into something shaped like a boat's keel*. *The stamens* E also are peculiarly disposed, as you may see. 2. They are ten in all (fig. 33), nine of which are united together at the base, one only F (fig. 34) being free. 3. They thus form a long tube, split open on one side, in which the *ovary* O (fig. 35) is situated. But the ovary will be much more easily examined when it has become a fruit or a pod.

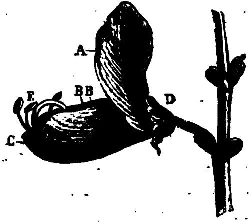

Fig. 31. — Flower of the common broom. Side view. — A, B, C, petals. — D, calyx. — E, stamens.

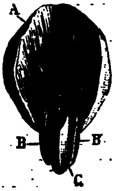

Fig. 32. — The same, front view. — A, B, C, petals forming the corolla.

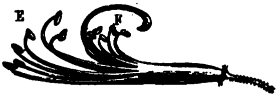

Fig. 33. — The ten stamens of the broom.

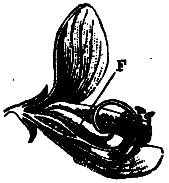

Fig. 34. — Nine of the stamens are united at the base, one only, F, is free.

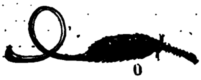

Fig. 35. — O, ovary of the broom plant.

And as the fruit, or pod of the broom, is very like that of the bean, I only have to recall it to your memory. Everybody knows what the *pod* of the bean is like, it looks almost as if it were a leaf folded in two, with its edges fastened together (fig. 36). Everybody has also seen, inside the pod, its

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1. How are the petals disposed? — *2. How many stamens* has this flower and how are they arranged? — 3. Where is the ovary situate?

edible seeds, called *beans*. 1. The bean being a large seed, you will easily discern the tiny plant between the two fleshy cotyledons which envelop it, and which will also serve, as we will afterwards learn, to nourish it when it begins to sprout.

And now next the broom and the bean, take the flowers of the laburnum, examine also its pods and its seeds, you will again find in them the same parts similarly disposed.

The flower of the lucern being less, is not so easily examined; but with patience and sharp eyes you will be able to convince yourselves that it also is of like structure.

It is quite reasonable then to put all these plants together under the same denomination. 2. So, as I have already told you, all of them come under the general **family** name of **Leguminosæ** (from the Latin *legumen*, vegetables, or pot herbs). This name has been chosen because many plants of this family are used for culinary purposes.

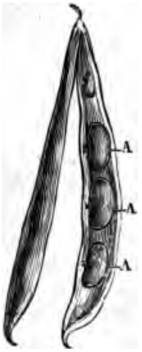

Fig. 36. — Pod of an open bean. — A, seed (bean) containing the little plant, and the two cotyledons.

73. The Rosaceæ. — Let us once more return to our *pear blossom*, and examine it more closely even than before, or better still we will substitute for it this wild rose (fig. 37), which is of the same family, and has a larger flower. You see it has 5 sepals A united together at the base, and containing first 5 petals B, then a great number of stamens C; lastly the ovary D, hidden within the calyx and adhering to it. Well, the flowers of the bramble, strawberry, medlar, almond, cherry and plum trees, etc. are all disposed very much in the same manner. Important differences exist only in the ovary, and consequently in the fruit, for we find amongst these plants to which we have just alluded, some that bear *fleshy fruit with pips* (pears, apples), others with *stones* (peaches, cherries, plums), others with but *little flesh*, and

---

1. What is to be seen in the pod, when the ovary has become a fruit, under the form of a pod, similar to that of the bean? — 2. What is the name given to the group of plants having the same characteristics as broom? Name some of these plants.

with kernels (almonds), etc. Yet on account of the similarity of their flowers, botanists have composed of all

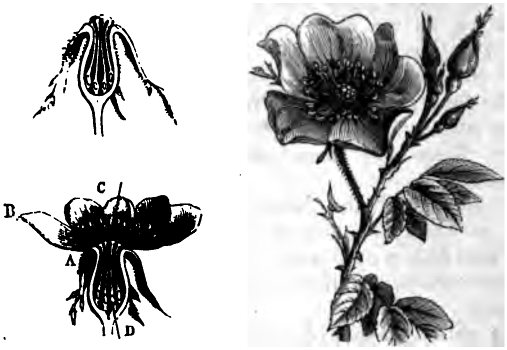

Fig. 37. — Wild rose. — A, calyx. — B, corolla. — C, stamens. — D, ovary.

these plants the **Rosaceæ** family, so called because their flowers have the same structure as that of the rose.

This shows the importance of the structure of the *flower*. Let us then continue to examine some of those that bloom in spring, at the same time as the pear.

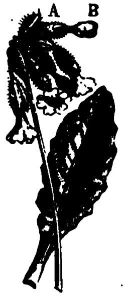

Fig. 38. — Yellow cowslip (Primulaceæ). — A, calix. B, corolla.

74. Primulaceæ. — See here is the *yellow primrose* or *cowslip* (fig. 38), found in abundance in our meadows during spring. You see it has five sepals joined together A, then five petals B, also united at their bases, so as to form a pretty long tube. Let us cut open this tube (fig. 39) : within it you will see, adherent to the side of the tube, five stamens C[1]. At the lower end of this tube is situated an ovary D, quite isolated and bearing a long style. This ovary will become a fruit or seed case, which when ripe will open at the top just like a real box (fig. 41).

Along with the primrose have been classed the blue and the red pimpernel, the cyclamen, etc. All these flowers form the family of **Primulaceæ**.

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[1] The section of the flower being in two parts, we can only show three stamens in the figure.

75. The Ranunculaceæ. — Here is a common *buttercup* (fig. 42). We find five sepals A, quite separate this time; five petals B also separate; a great many stamens (fig. 43), and in the centre a considerable number of small ovaries (fig. 44) which will hereafter become so many seed-boxes, each containing one seed. The buttercup is the type of the family of the **Ranunculaceæ**, to which belong also the clematis, anemone, pæony, and hellebore, etc.

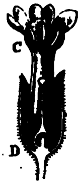

Fig. 39.
C, stamens. — D, ovary.

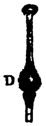

Fig. 40.
D, ovary.

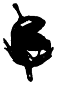

Fig. 41.
Fruit of the pimpernel.

76. The Asparagineæ. — See here is a stalk of the *Lily of the valley* (fig. 45), a flower very different from any we have yet seen. It has but one floral envelope A, which looks like a little round bell. This bell has on its edge six notches, which show us that there are here six petals blended into one, excepting at the very tips. At the bottom of the bell (fig. 46) are to be seen six stamens and an ovary, which will become a small fleshy fruit, properly called a *berry*. The lily of the valley is akin to Solomon's seal, the asparagus, etc.; it belongs to the family of **Asparagineæ**.

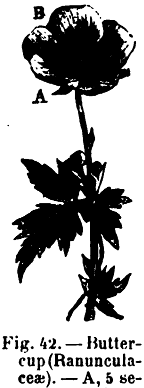

Fig. 42. — Buttercup (Ranunculaceæ). — A, 5 separate sepals. — 5 separate petals.

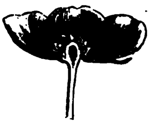

Fig. 43. — Open buttercup.

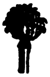

Fig. 44. — Ovary of buttercup.

77. The Amentaceæ. — The flower I now show you is as quiet and dull looking as possible (fig. 48), no brilliant colours has it to attract the eye. It is the flower of the *willow*, the one which bears stamens, for as I have already told you in those plants both kinds of flowers (flowers with pistils, and flowers with stamens) do not grow from the same root, but upon two different plants. This willow flower has neither calyx nor corolla, but merely two stamens A (fig. 49), situated at the base of a sort of little scale or bract B. The willow belongs to the family of **Amentaceæ.**

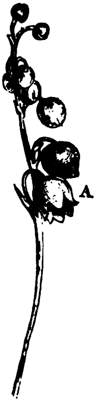

Fig. 45. — Lily of the valley (Asparagineæ).

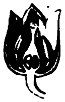

Fig. 46. Bell showing the stamens and ovary of the lily of the valley.

Fig. 47. — Ovary of the lily of the valley.

78. The Compositæ.— I will finish this lesson with the examination of one of those little daisies (fig. 52) whose white flowers adorn our meadows and road sides, and which, wrapped up as soon as evening falls in their pretty frills, seem to sleep snugly all through the dark night until the warm sunshine awakens them at morn, and invites them to unfold their wrappings and enjoy the bright and genial rays. Paul, I will trust you with this examination; but let me warn you that notwithstanding the modest look of the flower, it will give you no little trouble. In the first place, how many **sepals** A do you find? More than twenty. Indeed; and how many *petals?* If all those white blades B (fig. 53) are petals, there

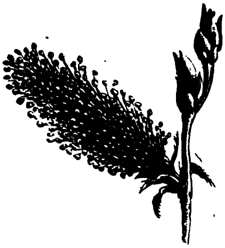

Fig. 48. — Flower and stamens of the willow (Amentaceæ).

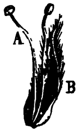

Fig. 49. A, stamens of the willow. — B, bract.

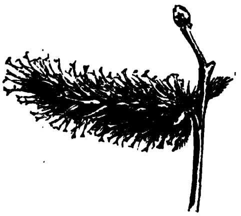

Fig. 50. — Flower and pistil of the willow.

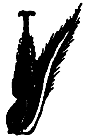

Fig. 51 Ovary of the willow.

are a great many. Well, count them, pray, and the stamens and the pistils also. Ah! Sir, I am altogether bewildered; the little yellow things (fig. 54) I took to be stamens are certainly something else, for I see with your magnifying glass that each has five notches: they look more like tiny flowers than any thing else I know! And flowers they are, my child. Each of those minute flowers has five petals joined together, forming a tube (fig. 55); inside are five stamens with a pistil which contains an ovule or tiny seed. All this can be seen with a good magnifying glass. Those small flowers are called *florets.*

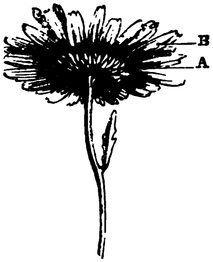

Fig. 52. — A daisy as seen from beneath.

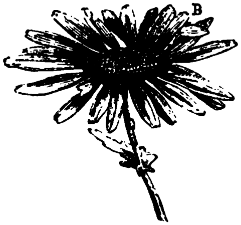

Fig. 53. — A Daisy seen from above (Compositæ).

A, crown of small leaves. — B, half florets.

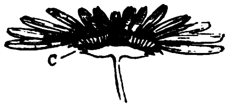

Fig. 54. — Section of a daisy. C, florets.

The white blades B (fig. 56), you counted at first as petals, are also flowers: each blade is composed of 5 petals blended together in a lamel B, at the upper end, and forming a tube D, at the lower. They are called *half florets.*

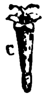

Fig. 55. — Floret of the daisy.

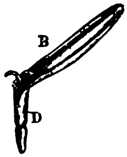

Fig. 56. — Half florets of the daisy.

Lastly, your so-called sepals are merely leaf-like organs called *bracts,* wreathed around the bunch of flowers, just like the leaves sometimes put round a bouquet.

The family to which our daisy belongs, well merits, as you see, the name of **Compositæ.** This is a very numerous and extremely varied family.

79. Principal families. — We have but few flowers at our disposal at the present time, early spring giving more green leaves than flowers. But as others come into view we shall find occasion to examinet he principal ones amongst them, and learn their structure, their family, and their name.

I shall now indicate briefly how we should classify the most important plants, those you know best or have heard most about.

We shall begin by the **Dicotyledons**. Here are the *Ranunculaceæ*, with which we are already acquainted.

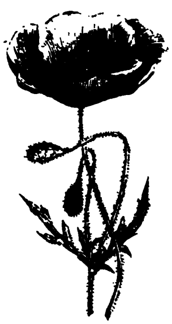

Fig. 57. — Papaveraceæ (Corn Poppy).

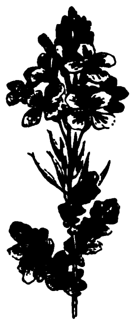

Fig. 58. — Cruciferæ (Colza).

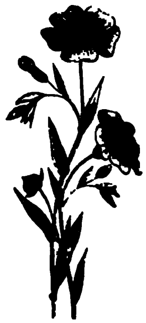

Fig. 59. — Caryophyllaceæ.

Then come the *Papaveraceæ* (fig. 57), among which we find the *Poppy* (in Latin *Papaver*), the corn poppy, and their allies.

The *Cruciferæ* (fig. 58) (a word which signifies *cross bearer*), thus named because their four petals are disposed in the form of a cross. This is a numerous family, which comprises wallflower, water cress, stock, mustard plant, cabbage, colza, radish, horse radish, etc.

The *Caryophyllaceæ* (fig. 59), to which belong carnation, pinks, soap wort, catch fly, common chickweed, flax, and many others.

The *Malvaceæ* (fig. 60), or mallow family, to which belong the mallow, marsh mallow, etc.

Leguminosæ (fig. 61). With which we have already made acquaintance.

The *Rosaceæ* we also know.

The *Cucurbitaceæ* (fig. 62), comprising the melon, cucumber, pumpkin, colocynth, etc.

The *Umbelliferæ* (fig. 63), whose flowers are borne upon little stalks all aggregated at the tip of the principal stem, and thence branching out, forming an *umbel*. Amongst these we find parsley, angelica, parsnip, carrot, chervil, hemlock, etc.

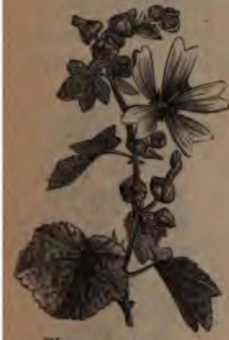

Fig. 60. — Malvaceæ (Mallow).

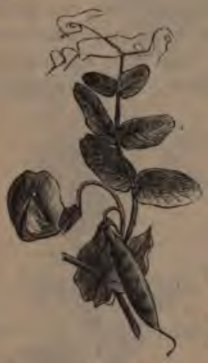

Fig. 61. — Leguminosæ (Cultivated pea).

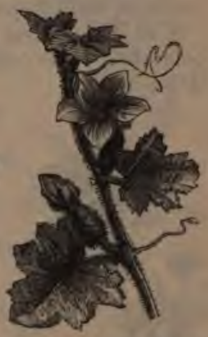

Fig. 62. — Cucurbitaceæ (Melon).

The *Rubiaceæ*, the *Madder family* (fig. 64), comprising besides madder, whose roots furnish a fine red dye: hence the name of the family *Rubiaceæ* (from *ruber*, the Latin for red), the coffee plant, cinchona, ipecacuanha, etc.

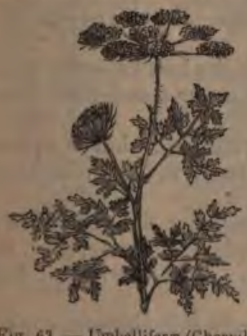

Fig. 63. — Umbelliferæ (Chervil).

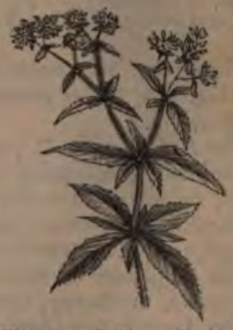

Fig. 64. — Rubiaceæ (Madder).

The *Compositæ* (figs. 65, 66, 67), family, in which there are three types. Some, like the daisy, have a wreath of half florets around a disc of florets; such are marigolds, sunflowers, Jerusalem artichoke, groundsel, chamomile. Others have only florets: the thistles are of this description, also burdock and artichoke. Others, that have only half florets, like chicory, lettuce, salsify, dandelion, etc.

The *Boraginaceæ* (fig. 68), comprising borage, vipers bugloss, heliotrope, and forget-me-not.

The *Solanaceæ* (fig. 69), amongst which are placed potatoes, bitter sweet, belladonna, henbane, tobacco, thorn apple.

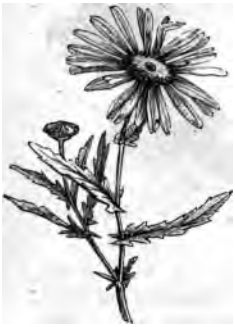

Fig. 65. — Compositæ (1 type Daisy).

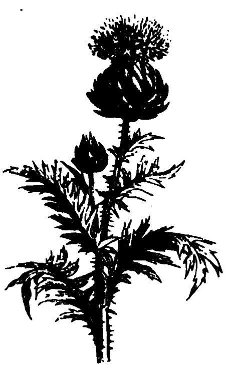

Fig. 66. — Compositæ (2 type Artichoke).

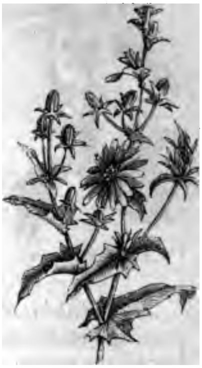

Fig. 67. — Compositæ (3 type Chicory).

The *Scrophulariaceæ* (fig. 70), the best known of which are digitalis or fox glove, veronica or speed-well, snapdragon, etc.

The *Labiatæ* (fig. 71), or mint tribe, that have a square-shaped stem, comprise mint, sage, thyme, marjoram, balm, rosemary, lavender, etc.

The *Euphorbiaceæ* (fig. 72) comprise the euphorbia or spurge, croton, boxwood, tapioca plant, dog's mercury, etc.

The *Urticinæ* or nettle tribe; with the hemp, hop, fig, nettle, mulberry, elm, etc.

The *Amentaceæ*: comprising the oak, chesnut, poplar, willow, walnut, hazel, birch and beech, etc.

The *Coniferæ* (fig. 73) (cone bearers, so called on account of their fruit), the greater number of which do not lose their leaves all at once, in the autumn, and therefore merit the name of *evergreens*. The principal members of

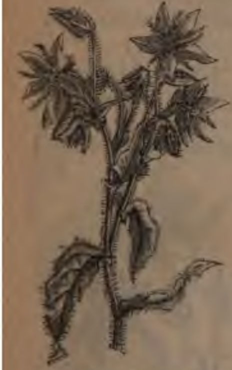

Fig. 68. — Boraginaceæ (Borage).

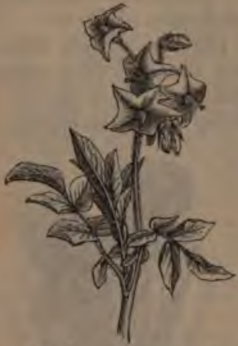

Fig. 69. — Solanaceæ (Potatoes).

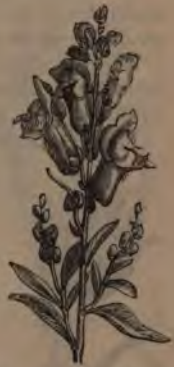

Fig. 70.—Scrophulariaceæ (Fox-glove).

this tribe are the pine, fir, larch, cedar, juniper, yew and cypress.

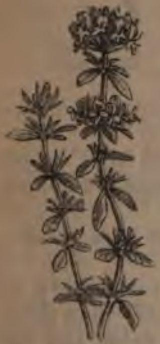

Fig. 71. — Labiatæ (Thyme).

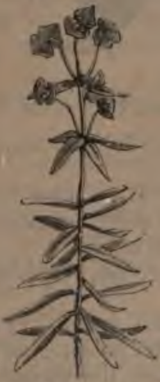

Fig. 72. — Euphorbiaceæ (Euphorbia).

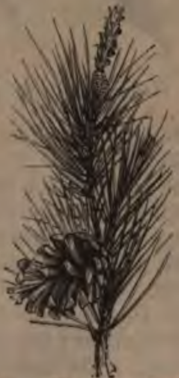

Fig. 73. — Coniferæ (Pine).

We now come to **Monocotyledons.**

When speaking of the *Asparagineæ* (p. 103, 4) I shewed you that its flower bore six notches, there being a union of *six* floral leaves to form it; instead of *five*, as with the majority of other plants which we had considered up to that time. In fact in most *Dicotyledons*, the parts of the flower (sepals, petals and stamens) are in sets of *five* or multiples of *five*, whereas in most *monocotyledons* they are in *three* or multiples of *three*.

The *Liliaceæ* (fig. 74) or *lily tribe*, plants with bulbous roots, among which are the tulip, garlic, hyacinth, onion, shalot, and aloe.

The *Iridaceæ* (fig. 75), iris and flag, gladiolus, saffron.

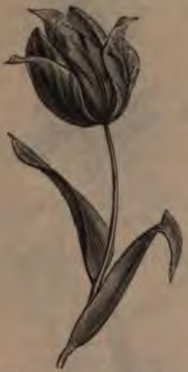

Fig. 74. — Liliaceæ (Tulip).

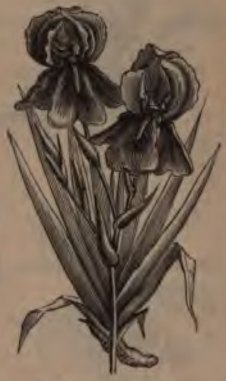

Fig. 75. — Iridaceæ (Iris).

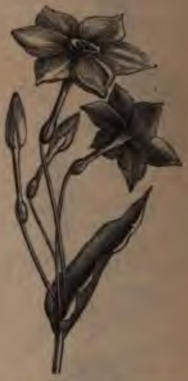

Fig. 76. — Narcisseæ (Narcissus).

The *Amaryllideæ* (fig. 76), narcissus, jonquils, snowdrops.

The *Orchidaceæ* (fig. 77), a most curious tribe, whose flowers have sometimes most fantastic shapes; amongst these we find orchis and vanilla.

The *Asparagineæ* (fig. 78), of which we have already spoken.

The *Palmeæ or Palm family*, to be found only in warm climates; the dwarf palm, rarely more than three feet high; the date palm, the cocoa-nut palm, and the sago tree.

The *Gramineæ* (fig. 79), comprising the *cereals*, that is to say, wheat, barley, oats, rye, rice, millet, maize; also the sugar-cane, bamboo, couch grass, darnel grass, alfa, and the greater number of good fodder grasses.

These are among the principal groups. We shall afterwards, in the course of somé botanical excursions in the country, learn further details about the form and structure of these flowers, and in short their peculiar *charac-*

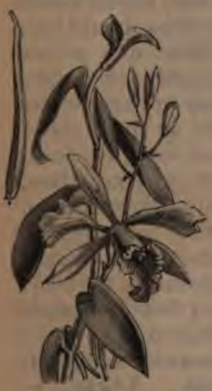

Fig. 77. — Orchidaceæ (Vanilla).

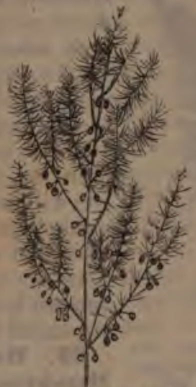

Fig. 78. — Asparagineæ (Asparagus).

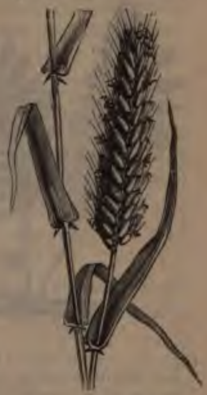

Fig. 79. — Gramineæ (Wheat).

ters. We must, for the time being, content ourselves with the foregoing dry nomenclature, which I should advise you to copy into your note books.

VI. — Flowerless Plants.

80. There is still a great category of vegetable organisms, that we have not as yet examined or spoken about.

All the plants we have passed in review *bear flowers*, sometimes reduced, it is true, to stamens and pistils.

There are plants, however, that *have no flowers at all;* and although they are perhaps less beautiful, they are by no means less interesting.

81. Ferns. — The first group of these flowerless plants of which we will take notice are the **Ferns**. In our country ferns are relatively small if compared to those found in warm climates, their stems being frequently several yards high. No doubt you wonder how it happens, that ferns, having no flowers, can nevertheless bear 'seed. Much might be said upon that question, for few subjects are more curious, or more interesting. I must, however, be content simply to lay before you a fern leaf, gathered from our own woods (fig. 80), and preserved in my *herbarium*. 1. See on the under side of this leaf, beneath each division, or as we should say, each *lobe*, those tiny yellow specks ranged in rows (fig. 81), they are aggregates of *sporangia* or spore cases. 2. If you examine them with my magnifying glass, you will see that these contain minute grains (*sporangiæ*), which in their turn contain the seeds (*spores*) of the fern; you can fancy that those seeds are small indeed.

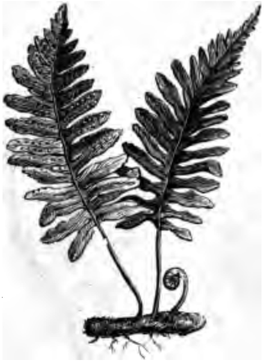

Fig. 80. — Fern leaf. — Under each lobe are little yellow specks (sporangia) which contain the seed.

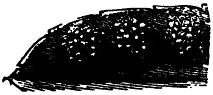

Fig. 81. — Sporangia magnified.

82. Mosses, Lichen, Mushroom, Algæ. — After the ferns, let us cast a glance at the **mosses** (fig. 82). 3. You are all well acquainted with them, and have doubtlessly observed amidst their foliage tiny balls B (fig. 83), borne on long slender stalks; those balls are cases that contain the seed.

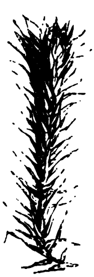

Fig. 82. — Moss.

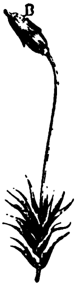

Fig. 83. — Cases containing the seed of the moss.

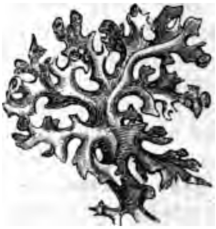

Fig. 84. — Lichen.

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1. What is to be seen on the under part of the lobe of a fern? — 2. *What do these* yellow specks contain? — 3. Where are the seeds of mosses to be found?

Next to these are the *lichens* (fig. 84), of which we have already spoken (page 83).

Then come the **Mushrooms** (fig.85), so varied in shape, in size, and in colour. You are aware, I am sure, that some mushrooms are edible, whilst others are terribly dangerous, although in outward appearance they are both much alike. 1. It is then most prudent to trust only to those cultivated on mushroom beds*.

Truffles are sorts of mushrooms that live under ground. 2. Some mushroom-like organisms are so very small that they cannot be discerned without the help of a microscope*. Such is *mould.* So also many pests of our vineyards and fields: all those mushrooms and their allies are termed fungi.

3. The **Algæ** (fig. 86) are plants that live in water. Some are very curious and very beautiful, especially amongst those that live in the sea.

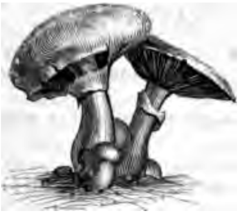

Fig. 85. — Mushrooms.

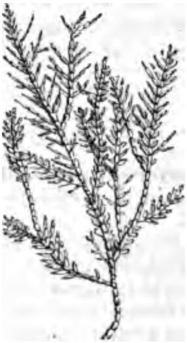

Fig. 86. — One of the higher Algæ (Coralline).

This is all I can tell you at present of the natural history of plants. In our walks we shall frequently find occasion to gain new information; and I hope to be able to show you a great many of the plants I have mentioned, and probably many others besides.

Now, before leaving the history of plants, I must tell you

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1. What sort of mushrooms can alone be eaten without danger? — 2. What is mouldiness? — 3. What are the Algæ?

that there exist most minute beings, so very minute indeed that it is only with the help of most powerful microscopes that they can be perceived, yet notwithstanding they play in nature a most important part.

You have perhaps heard of dire maladies that kill thousands of sheep every year, and not sheep only, but also oxen and even men. Many of these are produced by an extraordinary swarming in the body of little creatures called Bacteria, that look like minute crystal threads (fig. 208, p. 80). **1.** The mere prick of a pin that has been dipped in the blood of an animal suffering from these diseases, would be sufficient to cause death to a man.

2. *Putrefaction** also is caused by the development in dead bodies of similar little creatures. **3.** Those tiny beings, and many others akin to them exist, in a dry and inert state, in the dust that floats in the air; they are everywhere to be found, **4.** and when they fall upon dead animal or vegetable matter, they vegetate and grow like grains of corn upon arable* land.

SUMMARY. — PLANTS.

1. Different parts of a plant (p. 84). — An ordinary tree is composed of a **root**, a **trunk**, or stem, **branches, leaves** and **flowers**.

2. At the axil of each leaf, in the angle that it makes with the branch, you find a **bud**.

3. This bud, in growing, will produce a new branch.

4. All branches thus take origin at the **axilla** of a leaf, and every leaf bears a *bud* at its axilla.

5. Some branches, instead of lengthening out indefinitely, remain short, and are terminated by **buds**. These buds expand into **flowers**, which give birth to the **fruit**.

6. The trunk or stem (p. 85). — The trunk of the trees of our country is composed of three parts: in the centre is the **pith**, soft and white; round the pith is the **wood**, which is hard; and lastly, surrounding the wood, is the **bark**, which is often green on the outside.

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1. What effect is produced on man by the prick of a pin dipped in the blood of an animal afflicted with such a disease? — **2.** From what cause *is putrefaction produced*? — **3.** Where do you find these little creatures, and many others akin to them? — **4.** What is the cause of their development?

7. The pith does not occupy more space in an old tree than in a young one; in other words, the pith does not augment as the tree grows older.

8. The trunk of an old tree cut across presents a great number of *circles* fitting into each other.

9. Each of these circles corresponds to one period in the growth of the tree.

10. As the tree grew more rapidly when it was young, the circles near the centre of the stem are very distinct from each other; they become less and less so, as they get nearer the bark.

11. As to the wood, we can distinguish the *core* in the centre, which is harder, because it is older, and because in the course of time a solid matter has been deposited there, and the *sap-wood* (placed between the core and the bark), which is softer.

12. The trunks of our trees taper gradually towards the top, and terminate in a point : they are *conical*.

13. **The branches** (p. 87). — Stems give origin to branches in a great variety of ways. Sometimes they send out horizontal branches, as in the fir; sometimes they branch out in all directions, as in the plum-tree.

14. **The leaves** (p. 88). — Leaves are composed of a stalk or *petiole*, sometimes wanting, and a green part or lamina.

15. This lamina is sometimes *simple*, as in the leaf of the apple tree; sometimes *divided*, as in that of the butter-cup. It is still further divided in the leaf of the acacia.

16. **The Flowers** (p. 89). — The flower is composed of **sepals**, generally resembling little green leaves, the aggregate of which is called the *calyx*.

17. Next internal to these come larger leaves, generally coloured, which form the *corolla;* they are called **petals**.

18. In the centre of the flower you can see little thread-like stalks, at the ends of which there are yellow masses : these little stalks are the *stamens*, and the colour is produced by a very fine kind of dust called *pollen*.

19. Quite in the centre of the flower there are one or more balls surmounted by fine stalks. This ball is the **ovary**, the stalks are the **styles**, and complete, ovary and styles, is called the **pistil**.

20. **The Fruit** (p. 90). — It is the ovary which in course of time becomes the **fruit**.

21. In the ovary there are little white masses called *ovules :* these ovules will become the *pips* or *grains* that you see in the fruit.

22. **Seeds** (p. 93).— If you examine a seed, a bean, for example, or the kernel of an almond, you find two bodies called *cotyledons*.

23. Between the two cotyledons you can see a plant in miniature, in which you can distinguish a small **root** (radicle), a little **stem** with a tiny **bud** at the summit, plumule.

24. As for the cotyledons they are the two first *leaves*.

25. **Incomplete Flowers** (p. 91). — The important parts of

the flower, are the **stamens** and the **ovaries**, or rather the **pollen dust** and the **ovules.**

26. When the stamens of a flower are removed, the development of the ovary is completely checked, and the fruit does not *knot.*

27. Certain plants bear two kinds of flowers : the one possessing stamens, and the other the pistils (ovaries and styles).

28. Sometimes the two kinds of flowers are borne on different plants.

29. Structure of the palm-tree (p. 94). — The trunk of the palm-tree is everywhere of the same size : it is *cylindrical,* and not *conical.*

30. The trunk of a young palm-tree is as thick as that of an old one : it *lengthens,* but does not thicken.

31. In these trees there is **only one bud.** It is at the *top* of the tree, at which point the plant grows. There are no buds on the sides ; consequently no branches, but simply a large tuft of long leaves, stiff and hard, placed at the top of the tree.

32. There is no pith in the trunk, and no circles of wood fitting into each other, and no bark.

33. Instead of all this, a soft mass in which may be seen hard black fibres, which fibres originate in the leaves, and penetrate into the interior of the trunk, and then thread their way back to the surface again.

34. The seed of the palm-tree has but **one cotyledon.** This is the case with all plants of similar structure.

35. Dicotyledonous and monocotyledonous plants (p. 97). — Plants have been divided into two classes, **Monocotyledonous** plants, having only one cotylodon ; and **Dicotyledenous,** having two.

36. In each of these classes there are trees, shrubs, and grasses.

37. Duration of plant life (p. 97). — Some plants shoot in spring, flower in summer, and perish in winter ; such plants are called *annuals.*

38. Others give leaves the first year, flowers and fruit the second, and then die : these are *biennials.*

39. Others flower and give fruit several successive years : these are *perennials.* True perennial plants are generally **shrubs** and trees.

40. Lastly, there are plants perennial in the **root only,** and annual in the stem : such is the dahlia.

41. Classification of plants (p. 98). — Plant *families* have been established by grouping together under the same name all those whose **flowers** bear a great resemblance to each other. We have thus the families of the *leguminosæ,* the *rosaceæ,* and the *primulaceæ.*

42. Plants without flowers (p. 111). — Plants exist having no flowers at all. Such are *ferns,* whose seeds are borne on the leaves, *mosses, lichens, fungi,* and *algæ.*

SUBJECTS FOR COMPOSITION.

1st composition (p. 85). — The stem. — The pith; the place it occupies in the trunks of young trees, in those of old trees. — What is implied by the rings of wood. — Core and sap-wood.

2nd composition (p. 88). — Leaves. — What is seen at the axils of the leaves. — Simple leaves, complex leaves.

3rd composition (p. 89). — Flowers. — The different parts of a flower. — What does the ovary become?

4th composition (p. 94). — Palm trees. — Their trunk. — Their leaves. — Their seed.

5th composition (p. 97). — Duration of plant life.

6th composition (p. 101). — What may be seen in a bean.

III — STONES AND SOILS.

I — STONES.

83. Now that we have acquired some knowledge of animals and plants, we must set to work and learn something of the **ground** or **soil** on which we tread, and of the **stones**, or more properly speaking, the *minerals* of which it is formed. You will see that here also there is much interesting knowledge to be acquired.

84. Different constituents of the soil. — Of course you all know that soil is composed of many different constituents. **1**. You are able I am sure to recognise *arable* land*, that is, *earth*, which is tilled, and in which seeds are sown and plants cultivated; also *stones*, dispersed all through the soil, now in small fragments, again in great masses called *rocks;* and *sand*, in reality composed of very small stones; again *clay*, a sort of earth easily wrought, kneaded* and moulded*, which retains water in its hollows, being what is called *impermeable;* and which when baked, becomes hard, so that from ancient times until now, dishes and all sorts of pottery have been made with it. Lastly, all of you have no doubt seen or heard of pretty, regularly shaped stones, having what are called *angles*, *edges*, *faces;* which stones are called *crystals* (fig. 1).

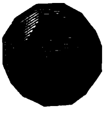

Fig. 1.
A cyrstal.

As we know what a classification is, we can see thatthis is already a pretty good beginning. Only we have learned not to depend on outward appearance alone. Let us then set to work, and look closely and attentively at all these things.

85. Action of Acids upon stones. — Here is a bit of **chalk** that I plunge into a glass of **strong** vinegar (fig. 2). **2**. *Tiny bubbles of air* (gas is a more

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1. What are the diverse constituents of the soil? — 2. What happens when a piece of chalk is put into strong vinegar?

appropriate word), *immediately ooze out of the stone and rise to the surface of the liquid, which thus seems to boil.* Now that I have stirred the contents of the glass with a bit of stick, you can see that the chalk has altogether disappeared; **it is dissolved** just as a bit of sugar would have been. We shall find the explanation of this in another lesson, when we come to study chemistry; we have verified the fact, and that will do for to-day.

1. I will now put into the vinegar a *bit of stone* similar to that with which the school-house is built; hard as this stone is, it also gives vent to gas and dissolves as the soft chalk did. **Marble** would be acted upon just in the same manner.

2. Now if I put a lump of **clay** (fig. 3) into the vinegar, the result will be altogether different; scarcely any gas will be set at liberty, the clay will spread itself out at the bottom of the vessel, and will remain there perfectly intact.

3. Here is, this time, a **bit of flint**, and a **pebble** I found in the bed of the river, which the water had washed down from some mountain rock, also a marble in **agate** : *upon these the vinegar has no effect at all, no more, indeed, than pure water would have.*

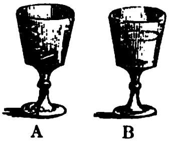

Fig. 2. Fig. 3.
The action of acids on stones. In A, the chalk dissolves in vinegar; in B, a piece of flint remains intact.

We will now repeat the experiment with a very strong acid that burns and destroys everything, *sulphuric acid*, which chemists sell under the name of *oil of vitriol.*

4. With great care, I take a drop of it on the end of a glass rod, and let it fall upon the **chalk**. See, such a discharge of gas, or *effervescence* as chemists say.

5. Another drop upon this bit of **marble**, so beautifully polished and seemingly so hard : the effect is the same. This should teach you, in passing, never to leave upon marble an orange or a bit of apple nor any other acid thing, else the marble would be very rapidly corroded.

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1. Under the same circumstances what would take place to a small piece of stone used for building? Marble? — 2. Piece of clay? — 3. A bit of flint? — A small pebble? — A marble of agate? — 4. If instead of vinegar very strong sulphuric acid were employed what effect would it have upon the chalk? 5. And on the marble?

1. *But upon* **clay**, *on* **flint**, *on the* **pebble**, *or the* **agate**, *the sulphuric acid has not the slightest effect; the drops we let fall upon them remain quite still, and occasion no effervescence.*

2. There exist then two kinds of stones : 1 *those that dissolve in acids, giving vent to gas*; 2 *those that are not affected by acids.*

86. Calcareous and silicious stones. — **3**. *Chalk, lime-stone, and marble, are called* **calcareous stones**. **4**. When submitted to a very high temperature in kilns constructed for the purpose (fig. 4), they become *lime* (in Latin **calx**, whence their name). Besides, whatever be their consistency they are never so hard as steel, nor even as iron. **5**. *Therefore a knife or even a nail can always make an incision.* **6**. On the contrary, flint and all stones akin to it, agates, etc., *contain no lime and undergo no alteration by fire.* **7**. Moreover they are so extremely *hard* that the point of a knife has no effect upon them, whilst they on the contrary, if they have a sharp edge, can cut marks even upon steel. **8**. And also if they are struck violently and sharply against a bit of steel, on the back of a knife for example, a fragment of steel is detached, which reddens under the force of the blow; this heated fragment is called a *spark*. Long ago, and yet not so very long ago, this property was applied to *kindling fire* (fig. 5); striking fire, as people used to say. — For

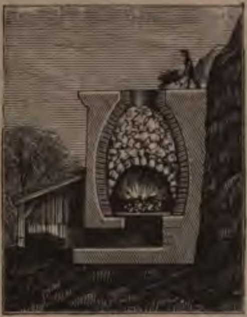
Fig. 4. — Lime kiln. When *calcareous* stones are submitted to a very high temperature they are transformed into *lime*.

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1. On clay? on a piece of flint? on a pebble? — 2. What classification can be established from the preceding experiments? — 3. What name is given to stones that dissolve in acids, such as chalk, common building stone, and marble? — 4. Into *what are calcareous* stones transformed, when submitted to a great heat? — 5. What other peculiarities do these stones possess? — 6. What becomes of such stones as flint when exposed to the action of fire? — 7. Under the action of the point of a knife? — 8. What happens when they are struck against steel?

this purpose tinder* was prepared, so as to catch the spark resulting from the blow. The tinder took fire as soon as the spark fell upon it. The same principle was also applied to guns (fig. 6), the spark in like manner

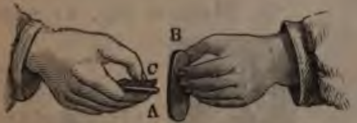

Fig. 5. — Flint and tinder. — The shock of the flint A, against the steel B detaches a fragment of the steel, which becomes red hot, and is known under the name of a spark: it sets fire to the tinder.

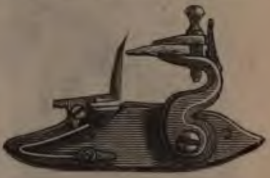

Fig. 6. — Lock of a gun. It is the spark which inflames the powder.

setting fire to the gunpowder. **1**. *All these extremely hard stones are* **silex**, *or rather* **silicious stones.** There exist a good many of them, and some are very beautiful, rare and precious. We shall afterwards have occasion to speak about them.

2. Sandstone, which is merely *grains of sand stuck together or agglomerated* is sometimes slightly *calcareous*, sometimes entirely *silicious*. This last variety, on account of its hardness, which allows even steel to be acted on, is used to make *whetstones*.

3. The stones projected by volcanic eruption are *silicious*.

87. **Plaster, slate, clay.** — Here is a kind of stone, which, although not very common, is very useful indeed. See how soft and yielding it is. I can scratch marks on it with my finger nail. **4**. Yet a drop of acid has no effect upon it. **5**. If exposed to a strong heat (fig. 7), it is reduced to a fine white powder, which you all recognise immediately; it is **plaster.**

6. The stone is called **Gypsum.** Great quarries of it exist near Paris; and for this reason the plaster it affords is sometimes called *plaster of Paris*.

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1. By what name are these hard stones known? — **2**. Does the division adopted for stones apply equally to sandstone? — **3**. What is the nature of volcanic lava? — **4**. What effect have acids on plaster? — **5**. What is the action of fire on this material? — **6**. What name is given to plaster?

1. The bit I showed you is a fragment of a statuette I bought some years ago at a fair. It came from Italy, where great numbers of similar statuettes are roughly cut out of a very white sort of gypsum, called *alabaster* (fig. 8)(from the Latin *albus*, white).

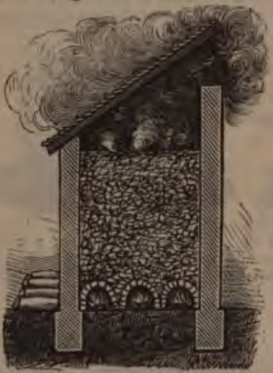

Fig. 7. — An oven for burning plaster. — *Gypsum* submitted to a great heat becomes plaster.

Fig. 8. — Statuette in alabaster. — White gypsum of Italy.

Fig. 9. — Man working at slate.

2. Slate is (fig. 9) well known to everybody; its hardness is about equal to that of calcareous stones, that is to say, incisions can be made in it with a knife. The finger nail cannot mark it, and acids have no effect upon it.

3. Clay is, as everybody knows, soft and easily manipulated, yet acids have no effect upon it.

4. Limestone, sandstone, gypsum, slate, clay, *are the most useful stones, or at least the most useful for you to know about.*

88. Stony mixtures. — You must not however believe that these rocks are always pure in their composition, or that they are distinct one from another. **5.** On the contrary, *calcareous rocks* generally contain some clay, whilst clay contains more or less calcareous matter. **6.** For instance, there is a well-known rock called **marl** (fig. 10), which is com-

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1. What name is given to a very white sort of gypsum that is found in Italy? — **2.** What is to be said *about slate*? — 3. About clay? — 4. Name the principal kinds of stones. — 5. Are calcareous rocks and clay always pure? — 6. What is *marl*?

posed of *calcareous* matter mixed with a strong proportion of *clay;* it is in fact for this reason that frost breaks it up so easily, and allows the rain to dilute and mix it with the soil.

Fig. 10. — The *marl* that is spread on fields is a calcareous rock, mixed with a strong proportion of clay.

1. What is known by the name of **vegetable mould**, or **arable soil**, is only a *mixture* of different kinds of stones reduced to fine powder, and mingled with animal and vegetable matter. See here is some garden mould quite freed from stones. Let us wash it carefully by shaking it gently under the tap of the water-cask (fig. 11). The water that runs off is muddy and dirty; it carries along with it a quantity of blackish matter. At last, by dint of shaking, nothing remains but some very fine and tolerably clean sand in the bottom of the glass. We will now add a little sulphuric acid. Immediately effervescence* ensues, and this indicates the presence of *calcareous* matter. Everything has settled down again, and you see there still remains in the glass a good deal of sand; this we can affirm is composed exclusively of grains of *silica* and *clay dust.*

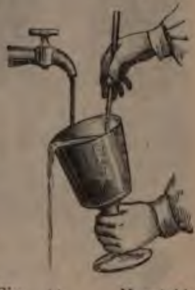

Fig. 11. — Vegetable mould, or arable soil, is a mixture of calcareous powder, grains of silex, clay dust, animal and vegetable remains.

89. Crystalline Rocks. — 2. Minerals, as I have already told you, often assume the form of what are called **crystals. 3**. There are, for example, *calcareous* crystals

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1. What is the composition of arable or vegetable soil? — **2**. Under what form are minerals often found? — **3**. Does the division adopted for stones apply also to crystals?

and *silicious* ones. *Gypsum*, a great mine of which exists near Derby, is often found crystallised in a spearhead shape (fig. 12). 1. Crystals of carbonate of lime (fig. 13), are of no value. One day, a poor peasant came, almost mad with joy, to tell me he had discovered a mine of diamonds. Those diamonds were simply some calcareous crystals that lined the interior of a large hollow stone. Great was his grief when I told him what his treasure really was, nor could he believe me until I showed him that my knife, with ease, cut marks upon them.

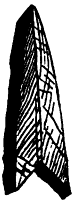

Fig. 12. Crystal of Gypsum.

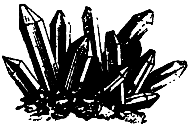

Fig. 13. — Calcareous crystals.

Fig. 14. — Marble statuary. — Statue of Denis Papin.

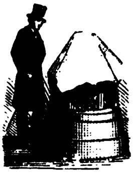

Fig. 15. — Enormous rock crystal in the Jardin des Plantes of Paris.

2. One of the most interesting amongst crystalline calcareous rocks is the **white** and beautiful ***statuary marble*** (fig. 14). A broken fragment of this marble looks quite like a bit of lump sugar; in fact, like lump sugar, it is composed of an assemblage of tiny crystals closely interlaced.

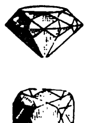

Fig. 16. — Diamonds artificially cut. Diamonds are pure crystallised carbon.

3. *Silicious crystals* are much prized on account of their great hardness, which allows them to cut marks upon glass, while it prevents them from being dulled like calcareous crystals.

4. One of the most common is **quartz** or *rock crystal* (fig. 15), often found in crystals as large as a man's head.

Others, rarer, of more brilliant aspect, and still harder than quartz, are found only in small crystals, and are eagerly and carefully sought out, and cut with facets to adorn jewels.

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1. What is the value of crystals of carbonate of lime? — 2. Name an *interesting calcareous* crystalline rock. — 3. Why are silicious crystals more sought after than calcareous crystals? — 4. Name a common silicious crystal.

1. They are called **precious stones**: *rubies* (red), *sapphires* (blue), *emeralds* (green), *topazes* (yellow), *amethysts* (violet).

Before passing on to more useful matters, I must tell you something about **diamonds** (fig. 16).

The diamond is the most beautiful of all crystals, the most brilliant and the hardest; it can cut glass or engrave upon all other crystals. Being the most precious, it is of course also the most expensive: a diamond of the weight of 15 grains is worth at least £ 250. **2.** And yet it is not a stone; it in nowise partakes of the chemical nature of other minerals. **3.** It is pure *crystallised carbon*. This is a most astonishing and almost incredible fact, on which we shall acquire some farther information in our lessons on chemistry.

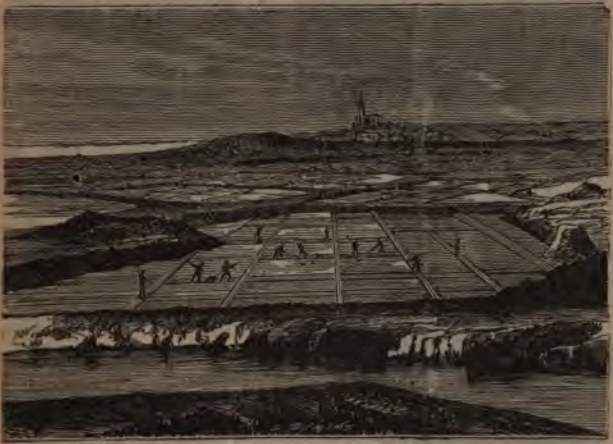

Fig. 17. — Salt Marsh, where salt is obtained by the evaporation of sea water

4. For the time being, keep in mind this one fact: *a diamond can be burnt just like coal*, only it requires a stronger heat.

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1. Mention some silicious crystals that are much sought after for jewellery. — 2. Is the diamond calcareous or silicious? — 3. What is the diamond? — 4. How do you prove that the diamond is carbon?

1. All the above mentioned crystals are very beautiful indeed, but of little real use. Others on the contrary are of very great utility; such as *Salt*, for instance, our common kitchen salt.

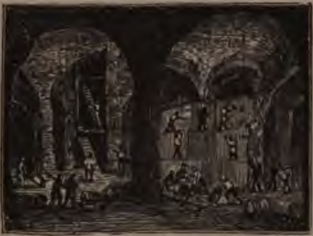
Fig. 18. — Mines of rock-salt.

2. A great quantity of the salt we use is obtained by the evaporation of sea water, in **salt marshes** (fig. 17). **3**. But this is not the only way in which this indispensable article is procured. Immense crystallised masses of it are found in the earth (fig. 18); it then takes the name of **rock salt.**

There are mines of rock salt in England and in France, but the most important salt mine in the world is that of Wieliczka* in Poland; in this mine, 600 feet underground, miles of galleries* have been made : this will give you some idea of its extent and importance.

90. 3. Crystalline Rocks. — Crystals are not always isolated. They are sometimes agglomerated in masses considerable enough to form stones and even rocks.

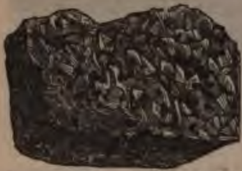
Fig. 19. — Fragment of granite a mixture of quartz, felspar, and mica.

4. Granite (fig. 19) is formed in this manner. All of you, I am sure, have seen granite. It is composed of three sorts of crystals interwoven as it were together : namely **quartz**, of which we have already spoken, **felspar** and **mica**.

5. Mica also is something with which most of you are familiar. In some countries the sea washes it ashore in such quantities that it is gathered and sold for next to nothing under the name of *gold powder*, which is used to dry up ink instead of blotting paper. See, I have

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1. Name a crystal less handsome than the preceding ones, but more useful. — 2. From what is salt *extracted?* — 3. Is salt found only in sea water? — 4. Name the three kinds of crystals that granite is composed of. — 5. Where is mica found? What is done with it?

some here; it looks like a great many thin and brilliant spangles of gold. Sometimes this same substance is found in sheets large and transparent enough to be used, in certain countries, as window panes.

The **felspar** (fig. 20) is less spoken about. It is notwithstanding of no small importance. Often under certain atmospheric influences, as yet insufficiently determined, it decomposes and crumbles into dust. **1.** This dust, carried away and washed by the rain, becomes what is called *Kaolin*, **2.** from which *porcelain* is manufactured.

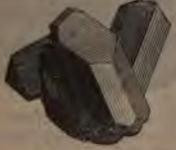

Fig. 20. — Fragment of felspar, which, under certain influences, becomes kaolin, of which porcelain is made.

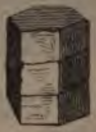

Fig. 21. — Fragment of basalt.

There exist a great number of rocks, more or less akin to *granite*. **3.** Those best known amongst them are the **porphyries**, composed of the crystals of felspar, set in a fine paste of felspar, like almonds in an almond cake; and **basalts** (fig. 21), of volcanic origin.

We have now passed in review the principal rocks and stones, hard, soft, crystalline or otherwise. But we cannot leave the history of things found in the crust of the earth without saying a word about **metals** and **coal**.

91. Metals and coal. — **4. Metals** are generally found under the form of **ore**, that is to say mingled with other bodies. Although sometimes found on the surface of the ground, they are generally more or less deeply buried, necessitating the hollowing out of *mines* * for their discovery and extraction. **5.** The *ore* exists in the earth sometimes in pretty large masses, sometimes

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1. What becomes of felspar when decomposed and reduced to dust? — 2. What is made of kaolin. — 3. Amongst the best known rocks name two akin to granite. — 4. Where are metals found, and in what condition? — 5. What do they form in the earth?

in **veins** (fig. 22), which the miner must carefully follow up, as one would follow the pipe of a stove in order to remove the soot.

It happens at times, that rocks containing *ore* crumble to pieces from the effects of frost and rain, and then are rolled away and broken up by torrents and rivers. The metal, being heavy, *falls* to the bottom in deep pools and quiet nooks. This is why gold is often found in the former beds*, as well as in the actual channels, of certain rivers.

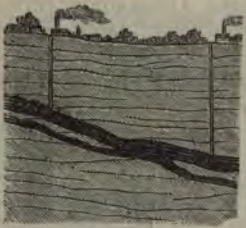

Fig. 22. — A section showing a metallic vein in the earth worked by means of mines.

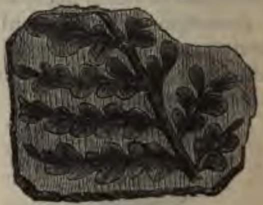

Fig. 23. — A fragment of coal bearing the impression of a fern leaf.

Fig. 24. — Interior of a coal mine.

1. Coal is the residue of *immense forests* buried in the earth during a prodigious number of years. Those forests were composed mostly of enormous ferns (fig. 23) and trees somewhat akin to our firs. In order to procure the coal out of the depths of the earth you know that great pits called mines are dug, and subterranean galleries are made (fig. 24).

2. The **turf** or peat in formation at the present day *is very young coal* not yet buried. The plants of which it is composed are still recognisable.

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1. What is coal? — **2.** What is turf?

II — ROCKS.

You must not fancy that *calcareous* stones, *clays*, *slates*, *silicious stones*, are mingled together in a heterogeneous fashion in order to form the soil on which we tread. No, you already know that this is not the case.

And before proceeding further, I must acquaint you with the fact that the term *rock* is applied by mineralogists, not only to the stony matter familiarly called *rock*, but also to all the massive mineral substances which compose the crust of the earth, be they as soft as clay, as friable as chalk, or as hard as flint.

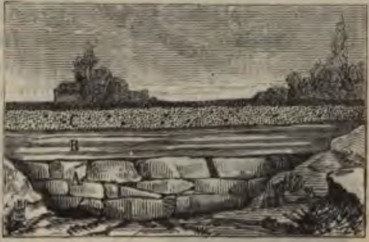

Fig. 25. — An open quarry. — A, calcareous stone B, clayey earth. — C, sandy soil.

92. In one of our recent walks, we went to visit the quarry on the hill side. You may remember I pointed out to you the lowest part of the excavation, A (fig. 25), formed of *calcareous stone*, commonly called limestone, with which the village is built. Above these we saw B, a layer of clay which supplies material for the tile works of Henry's father. And lastly, upon the top, a layer C, of sand, bestrewn with pebbles like those you find in the river at the foot of the hill.

1. The neighbouring hill is composed of three superposed layers : namely *calcareous* rock, *argillaceous* rock, and *sandy soil.*

93. *Beds or layers.* As we made a pretty long visit to the calcareous or limestone quarry, I drew your attention to the fact that the *blocks of stone were disposed with perfect regularity*, *one upon another*, just as if

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1. What name is given to all the different kinds of massive mineral substance that form the crust of the earth?

some giant had carefully piled them up. **1.** From place to place, I showed you horizontal bands separating *layers of stone*, slightly differing from one another in colour and consistency. In other words, I made you observe that the quarry *was formed of several regularly superposed* **strata**.

In climbing the steep road cut on the slope of the hill, we passed by the precise spot where the calcareous strata finished off and the layer of clay began. There also *we saw, that the line of separation was as straight and level* as those which divided the different strata in the stone-quarry.

Now what do you think could have brought such an agglomeration of stones there, and how does it happen that they are so neatly and so regularly arranged?

94. Marine organisms in the ground. — The question certainly appears a very difficult one. But here is something that will help us to find an answer. **2.** The owner of the quarry, Mr. Jones, gave us some fossilized shells, and James, who went climbing about everywhere, found here and there great numbers of them: these are *shells changed into stone.*

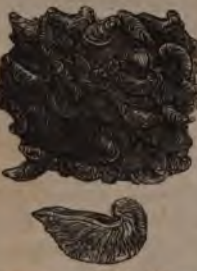
Fig. 26. — Fossil oysters.

Let us examine these shells (fig. 26). At a glance we can detect their resemblance to common oysters. And oysters, as you well know, live in sea water. **3.** Hence the conclusion that the *sea once lay above our quarry*, and that these oysters lived in it, as those of our days live on the rocks under the waves; that after the death of these oysters, slimy mud and sand of a calcareous nature were deposited on their shells. **4.** That after all this, a time came when the sea disappeared, *when the mud, sand, and shells stuck together in the process of drying, and formed thus the calcareous stone we have now before us.* Things

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1. Are the different kinds of stone in a quarry all mingled together? — **2.** What are often found in *quarries?* — **3.** What does the presence of these shells, changed into stone, prove? — **4.** What become of the mud, sand, and stones when consolidated in a mass?

cannot be explained otherwise. Moreover it has been proved that the like is now going on in several places on the sea-shore.

95. Apparent movements of the sea; movements of the ground. — But, you may ask, how can it be that the sea, which is far off at the present day, should have at one time covered with its waves a great part of our hill, and risen 350 feet at least above its present level? And again, if it once was there, how is it that it has so completely disappeared?

There are only two ways of explaining this.

The first would be to suppose that there was at one time much more water in the sea than there is now, as its level was 350 feet higher than at present. And yet that would not suffice, for marine shells are found in the Alps* and Pyrenees* at more than 9000 feet above the level of the sea.

And again if this were the case, what could have become of such an immense quantity of water? Evaporated into the air? But the firmament would not suffice to hold so many clouds. Could it have sunk into the earth? We shall afterwards see that it is far too warm for water to remain there. This cannot then be the real solution.

1. The second explanation would lead us to suppose, *that it is the* **bottom** *of the sea that has* **been heaved up** *so as* **to emerge out of the water**, *which latter has changed place without diminishing in quantity.*

Which of the two explanations do you prefer, Paul? Sir, I see that the first will not do. And for the second, I cannot see how it could do either. The earth is so solid! Papa, who has been on the sea, says that the water is constantly in motion; whilst on dry land, everything is quite still and steady. Well, my child, let me tell you, that the dry land is not so still nor so steady as you fancy. True, its movement is so slow that we do not feel it. **2**. But *it rises here and falls there, and in some places it rises or falls alternately.*

Obvious proofs of this exist at the seaside in various places. At Pozzuoli (fig. 27) in Italy, the Romans built

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1. How do you explain the occurrence of marine shells, at the present day considerably above the level of the sea? — 2. Is the ground on which we walk immovable?

a temple on the sea shore. The ground having subsequently sunk, the sea invaded the temple long enough to allow marine shells to burrow* into the columns some yards above the pavement. Since then the ground has again risen, and at the present day the traces of the marine shells are at a considerable height above the water. The same phenomenon is taking place slowly in our days on several coasts. **1.** The coast of Norway, for instance, is sinking gradually, whilst that of Sweden is emerging more and more, and the Baltic* is becoming shallower. Landmarks made on the Swedish coast by the celebrated naturalist Linnæus* at the beginning of the eighteenth century, show that this upheaving raises the coast about four feet in the course of a century. There is nothing surprising then in the fact that the bottom of the sea should have risen here to the height of 350 feet above ist actual level. **2.** Many centuries have passed away since that time! But *centuries*, that to us seem so long, are but *moments*, when compared to the prodigious periods of the past. In short, science makes us sure at the present day that the second explanation is the true one. The sea came this far formerly, covering all the

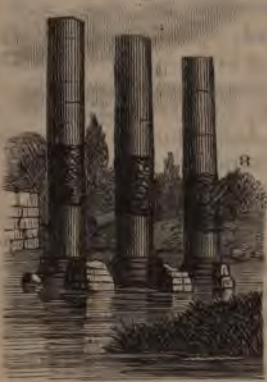

Fig. 27. — Temple at Pozzuoli in Italy. — B, marine boring shells indicating that the earth had once sunk to this depth below the sea.

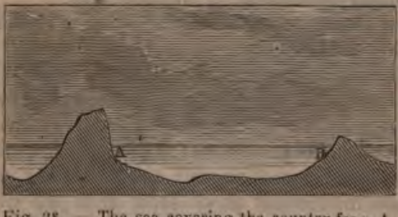

Fig. 28. — The sea covering the country from A to B.

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1. Name a modern example of the changes in the position of land. — 2. Do these changes take place quickly or slowly?

surrounding country from A to B (fig. 28), and depositing regularly and slowly its material held in suspension and its shells. Afterwards the bottom of the sea was upheaved, and A′B′ (fig. 29) with all its land sediments became dry land. Do you understand now, Master Paul?

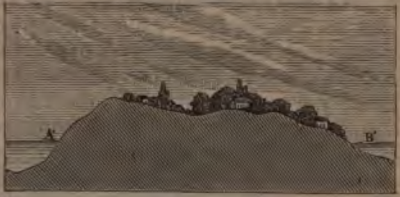

Fig. 29. — Then the bottom of the sea rose to A'B'

96. Differences between the superposed strata. — Yes, Sir, I do. But why is it that the limestone beds are not alike from top to bottom of the quarry, and that there are, as you told us, *several strata?* **1**. *It is very probable*, my child, *that during this uprising of the bottom of the sea, the rivers and currents did not always bring along with them the same kind of matter, and did not deposit their sediments in the same place.* For we can ourselves observe similar, though smaller changes, the waves depositing alternately on the same part of the seashore fine sand or large pebbles.

97. Fossils. — More than this. **2**. *During* the **immense length of time** *that this upheaving continued, even the nature of animals* has changed. In the same place, but at a different height, the species, or rather their remains, are not alike. In our quarry we find not only oysters but also many other kinds of marine molluscan shells (fig. 30).

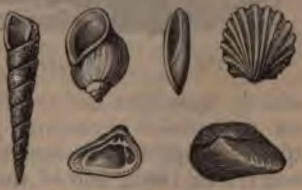

Fig. 30. — A few fossils.

3. Now in the upper strata these **fossils**, as they are called, differ notably from those found in the lower.

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1. Why is it that on the limestone there are placed different successive strata? — **2**. What other phenomenon is produced during the enormous duration of time required for these upheavals. — **3**. What name is given to the petrified remains of animals during these different periods?

98. Real divisions of stratified Rocks. 1. We must then divide such rocks *not only according to the nature of their component stones, but also, and especially, according to the nature of the* **fossils** *found in them.* For at seaside places, at no great distance from each other, sometimes clayey substances are to be met with, sometimes calcareous deposits. Only the inhabitants being the same, the shells are so also, and would form the same kinds of fossils. Thus on the opposite side of the valley*, there is sand containing fossils exactly the same as those found in the upper strata of our quarry. We may hence conclude that they have been deposited there **at the same** period generally speaking as those we found in the stone-quarry.

99. Causes of the movements of the ground. — And now, Master Paul, does this satisfy you? Is there anything else that puzzles you? Yes, Sir, there is. Ah! What now? Well, Sir, I should like to know what can move and heave up the earth so? It must be very heavy, and require prodigious strength!—Ah! this is really difficult to answer. And the most learned know but little on the subject, and have been reduced to make suppositions.

Fig. 31. — Earthquake.

2. *It is more than probable that the cause which thus gently and slowly upheaves the crust of the earth, is the same as that which occasions from time to time* **earthquakes** (fig. 31) *in some parts of the world.* Recently, in 1881, one of these terrible commotions destroyed the town of Chio*, and killed thousands of its inhabitants. The poor dry land, in such circumstances, is about as much in motion as the heaving seas.

3. *Earthquakes are especially common in the vicinity* of *volcanoes.* In South and Central America, for instance, or again in Asia Minor, and the south of

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1. How must rocks then be classified? — 2. What is the cause *that makes the earth* rise and sink so slowly? — 3. What countries are most exposed to earthquakes?

Europe. The neighbouring volcano generally breaks out into eruption simultaneously with an earthquake (fig. 32).

You have all seen a kettle lid jump up and down when the water boils too quickly. Well, it seems as if the earthquake were the leaps of the lid, and the eruption of the volcano the escaping of the steam, carrying with it what happens to be inside. Only it is on a larger scale! 1. And then it is not a little boiling water that is expelled, but immense stones that are projected, and enormous volumes of steam and lava, melted by the great heat of the volcano. The lava streams flow slowly over the ground, covering up and destroying everything they meet.

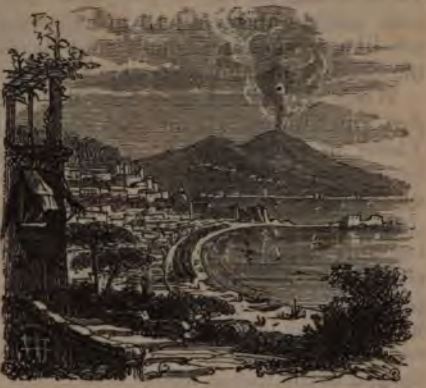

Fig. 32. — Volcanic mountain (Vesuvius) in eruption.

Some volcanoes now extinct, vomited lavas, different from those thrown up by volcanoes actually in activity, Those lavas are called *basalts* and *trachytes*. The different kinds of *porphyries* have also been brought up out of the very bowels of the earth, and more or less spread out on the surface.

100. Igneous and Aqueous Rocks. — 2. In short, you see, my children, from what I have just been telling you that there are two sorts of rocks : 1. *Rocks or soils formed by water*, or **Rocks of aqueous origin** (from the Latin *aqua*, water); 2. *Rocks formed by matter brought to a state of fusion, by a very high temperature*, or **rocks of igneous origin** (Latin : *ignis*, fire).

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1. What phenomenon accompanies earthquakes?

2. What are the two principal classes of rocks?

101. Salt Water Rocks, and Fresh Water Rocks. — **1.** Among the *rocks of aqueous origin*, some have been deposited by sea water, others by fresh water from large lakes. They can be distinguished from each other by the *fossils* they contain. Those found in the former, have more or less affinity with marine animals still in existence; while the latter are like fresh-water shells and fishes. There are also the remains of land animals.

When an animal dies upon land, it becomes *putrified* *, and in a short time nothing remains but the bones. These in their turn, attacked by insects, water, air, frost, and the heat of the sun, decay, and in no great time disappear also. If, on the contrary, the dead body be carried away by a river so as to fall into the deep and tranquil water of a lake, it sinks to the bottom and is covered up with mud; *its bones become mineralized* (*turned into stone*), *and remain as* **fossils** when the waters of the lake disappear. This can also happen in sea water, but not so readily, on account of the constant motion of the waves, etc.

2. Therefore, *it is especially in fresh-water rocks that the remains of terrestrial mammalia* *, *of birds, and reptiles* **are found.*

3. It is easy to understand that no fossils are found in *Igneous* rocks, since they have extruded from the burning depths of the earth.

102. Order of superposition of Rocks. — **4.** People who study the history of the earth, and who are called **Geologists** (from the Greek, *gê*, earth; *logos*, study), have distinguished, *by the examination of fossils*, a great number of strata, to which they have given names, and which they have classed according to their relative ages.

When one rock covers another, it is certain that the upper is of more *recent formation*.

Now, rocks lie disposed in *regular strata*, like leaves of books piled one on another. The oldest

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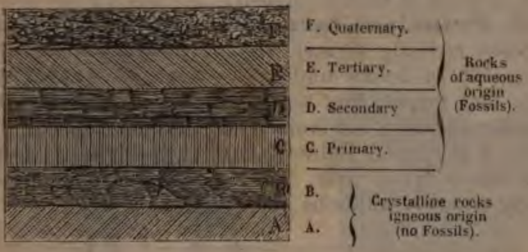
1. What distinction is made amongst rocks of aqueous origin? — 2. In what class of rocks are fossils *found*? — 3. In what class of rocks are fossils never found? — 4. By what means have geologists classified the different strata?

known of these rocks are crystalline, and contain no fossils (fig. 33, AB).


F. Quaternary.
E. Tertiary.
D. Secondary
C. Primary.
B.
A.
Rocks of aqueous origin (Fossils).
Crystalline rocks igneous origin (no Fossils).

Above these come *rocks, undoubtedly deposited by water*, in which are to be found the remains of organisms of the animal and vegetable kingdom.

1. *The more ancient the soils are, the greater are the differences between the animals whose remains are found in them, and those that people the earth at the present day.*

In those beds, immediately above the ancient crystalline rocks, but few fossils are to be found; and those met with belong to the most inferior groups of the animal kingdom. Then as the strata rise one over another, and as we near the present epoch, the animals appear more and more highly organized. Monkeys and men are of quite recent date.

Let us understand each other, however : « recent » in regard to geological epochs, they certainly are, that is to say, they appeared last! But if we wished to count by years, centuries, thousands of years, the length of time since man existed on the earth, we should find the task too great and the length of time incalculable. And in geology it is always thus. One can say, this rock is of more recent formation than the one under it, and more ancient than that which is above; but at what epoch it was formed, and how long a time its formation lasted, no one can tell. There are some limestones, composed of shells so very small, that the naked eye cannot discern them, millions of these shells existing in a cubic inch.

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1. What is the result of the antiquity of rocks, so far as the animal species is concerned?

Yet these rocks are in beds hundreds of yards thick, think then how many centuries must have rolled by during the formation of such a deposit!

105. Principal formations. — 1. Thus it is in the most recently formed rocks, which you will find designated in books under the name of **quaternary** *rocks*, that for the first time, remains of man or traces of human industry are found.

And a very poor industry this at first was. Man in those times lived wild, in caves along river banks, hewing roughly silicious stones for weapons.

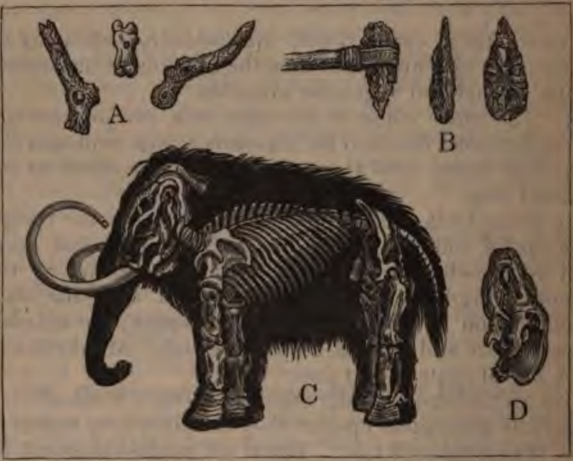

Fig. 34. — A, bones of reindeer carved. — B, axes cut out of flint. — C, skeleton of a mammoth. — D, skull of enormous bear.

He had to battle, even on what is now European ground, with *elephants*, mammoths (fig. 34), *rhinoceroses*, *tigers*, and gigantic *bears!* Naked and almost unarmed as he was, he slew them and made food of their flesh, utilising even their bones for the manufacture of various utensils. All this took place thousands of years before history existed to record his life, his struggles, and his victories.

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1. In what rocks are found human remains, and traces of human industry?

1. In the earlier or **Tertiary** epoch, the end of which saw *monkeys* appear, perhaps even *man*, there were in Europe very large lakes of fresh water, upon the shores of which lived numbers of *mammalia*, widely different from those known in our day (fig. 35). The French naturalist Cuvier*, first gathered together and studied their bones, and thereby was able to describe animals that had lived in those far-distant times.

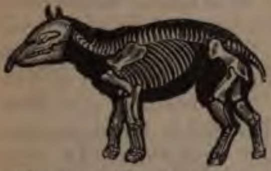
Fig. 35. — Paleotherium (size of an ass).

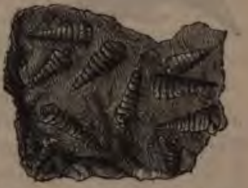
Fig. 36. — Fossil shells in a fragment of Paris rock.

It is on tertiary soil that London and Paris are built; and in this, great numbers of *fossil shells* (fig. 36) are to be found, similar to those existing at the present day in brackish and salt-water.

2. During the epoch that preceded this, namely, the **secondary** period, great parts of England and France were covered by the sea. At that time there lived in its waters, *molluscs*, *fishes* and *reptiles* unknown in our days, the finned reptile called *Ichthyosaurus* (fig. 37), for instance, which is not unlike a whale. The remains of very few terrestrial animals have been handed down to us through these centuries, but strange are those few we know. Here is a flying reptile, something like a bat, the *pterodactyle* (fig. 38). Only one bird of that remote period is known, and it has teeth and a long articulated tail like a lizard.

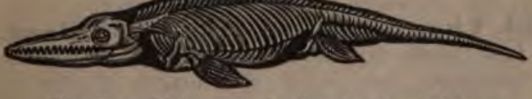
Fig. 37. — Ichthyosaurus (medium size, twenty feet).

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1. What epoch precedes the quaternary epoch? — 2. What is that which precedes the tertiary epoch?

Fig. 38. — Pterodactyle (size of a pigeon).

1. More ancient still than the preceding are the **primary** rocks, C, of which the most important for you to learn about are those containing *coal*, they are called *coal* measures. At this epoch, great *forests* covering wide extents of ground were buried, so to speak, under water, and there, slowly transformed into coal. You know that the principal coal mines* in England are those of Newcastle, Lancashire, Yorkshire, Staffordshire, and South Wales, in France those of St. Etienne in the department of the Loire, and those of the department du Nord, which last are in the vicinity of the great Belgian mines. Almost everywhere, coal must be brought up from great depths, as the coal measures are so often covered by the secondary and even tertiary strata.

Slates occur usually among rocks still older than the coal measures.

This is all that need be said on this subject for the present course of lessons. I hope you have properly understood all I have told you, so I will recapitulate rapidly.

2. First, there are the very ancient *crystalline rocks*, B, superposed in regular layers : then rocks of aqueous formation: *primary*, *secondary*, *tertiary*. Lastly, the *quaternary* rocks, which make a category apart, and on which much might be said.

104. Changes in the map of England. — If I have made myself clearly understood, you should be convinced that since the origin of the world the aspect of the earth has undergone marvellous changes. 3. *Oceans have taken the place of what was, in most cases, dry land. And what is dry land now-a-days is, in most cases, what was the bottom of oceans that have been upheaved.*

Practically all France and England have been submerged*, once or several times; the sea encroaches here,

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1. What is the epoch which precedes the secondary? — 2. In what order do the different rocks succeed each other, beginning with the most ancient? — 3. Has the earth always presented the same aspect, as it now does? —

recedes there and sometimes reinvades regions that had at other times been lifted above its level: I here show you two maps that indicate the state of land and water during the primary (fig. 39), and the secondary epoch (fig. 40).

105. Is there anything under the ancient crystalline rocks? — And now has any one any other observations to submit, or any other question to ask? What do you wish to say, James?

Please, Sir, do the crystalline rocks go to the very bottom of the earth, or is there any thing under them?

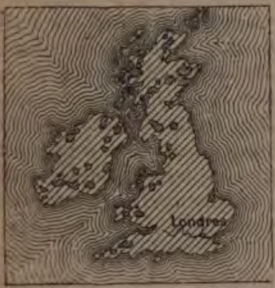

Fig. 39. — Map of England during the primary epoch.

▩ Emerged land*.
▨ Submerged land*.

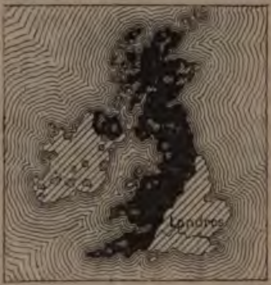

Fig. 40. — Map of England during the secondary epoch.

▩ Emerged land* (primary epoch).
■ Emerged land* (secondary epoch).
▨ Submerged land.

Ah, you ask me questions that are hard to answer. What there is under these ancient rocks, no one ever was able to see, as I have already told you. But the volcanoes seem to reach very far down into the earth, the lavas they throw out undoubtedly come from enormous depths.

In that case, the interior of the earth would be *lava*. — But, Sir, the lava is fearfully hot; how is it that it does not overheat all the earth so as to scorch our feet? And how does it come to be so very hot?

106. Central heat and the crust of the Earth. — Well! be all ears, my child, and follow attentively what I am going to tell you. 1. When a deep

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1. Is the temperature of the earth the same at the bottom of a deep mine, as it is on the outside?

hole is made in the ground, the *deeper it is made the greater the heat is down at the bottom.*

1. In a mine of 3000 feet in depth it has been ascertained that the *augmentation of heat was one degree centigrade in* 100 *feet.* That makes 30 degrees for 3000 feet. 2. If the same progression continues thus for 300,000 feet, the temperature would attain 3000 degrees. This is far more than is necessary to melt lava, granite, etc. 3. Serious investigations and study lead to the belief that matter in a state of *fusion* would begin at the depth of 150,000 feet, were not the pressure so great as to prevent actual melting.

Now, geography has already taught you, and we will study this question also, that the earth is a globe whose diameter* measures about 8000 miles. 4. You see then *that this globe is almost entirely in a highly heated state, with but a little comparatively cold crust all around,* which crust does not represent more than the hundreth part of the total thickness of the globe. *This is much less in proportion than the thickness of an orange skin compared to the orange*

The term " crust of the earth " is indeed only applied to that part of which geologists have accurate knowledge.

107. Some explanations of the changes that the earth has undergone. — It is very certain that there was a time when our earth was a ball of melted matter, still luminous*, something like red-hot iron. Gradually the earth grew cooler by turning and rolling through space, the materials became more compact, and a first crust was formed, composed perhaps of *granite* and *crystalline rocks.* When this crust by the progress of cooling grew thick enough to prevent the surface from being burning hot, water was formed, and became seas and oceans, and the heat diminishing still more, living beings appeared. These oceans driven hither and thither on the surface of the globe by the movements of the terrestrial crust, thinner and less solid than it is now, deposited the rocks of which I have spoken to you, and with them their fossil contents.

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1. In what proportions is the heat *augmented*? — 2. Reckoning thus, what would be the temperature at a depth of 300,000 feet?

The same thing continues to this day, only with less energy and activity as the thickness of the crust increases.

During those periods long passed away, great movements took place in the ground, upheavals, depressions, fractures, or rents. In mountainous countries, the strata, deposited quite flat by the sea, were sometimes upraised to an almost vertical* position. The interior of the earth has, notwithstanding the crust, always been in communication with the outer parts. Melted matter has been thrown out, and is so still from time to time. At first it was great quantities of matter such as the *porphyries*, that came to the surface through the thin crust they broke open. At a later period, sorts of chimneys or volcanoes threw out primitively *basalt* and now-a-days *lava*.

This is the history of our Earth. It is no fiction in which imagination and invention play the first parts, as they have so often done in similar circumstances, but real history, of which science is as sure as it is possible to be about things no eye has seen, and on which one can but reason.

SUMMARY. — Rocks.

1. **Different kinds of stones** (p. 120). — Stones may be roughly divided into two categories : 1. stones that dissolve in acids, giving vent to gas; 2. those that remain uninfluenced by acids.

2. The former, among which are to be numbered *chalk*, *limestone* and *marble*, are designated by the name of **calcareous stones,** because when submitted to a very high temperature, they become *lime* (in Latin *calx*).

3. The latter, the principal type of which is *flint*, are for the greater part **silex** or rather **silicious stones.** They resist the action of fire, and are extremely hard.

4. Clay is numbered among silicious stones.

5. **Stony mixtures** (p. 122). — The different kinds of stone are frequently mingled together.

6. **Marl** is a *calcareous* stone in which exists a strong proportion of *clay*.

7. **Arable soil** is a mixture of *animal* and *vegetable* detritus, tiny *calcareous* stones, grains of *silex* and *clay* dust.

8. **Crystalline stones** (p. 123). — Minerals are frequently seen under the form of *crystals*. There are *calcareous* crystals and *silicious* crystals.

9. *Calcareous* crystals as well as *gypsum* crystals are of no value, because being tender, they are easily scratched and tarnished.

10. *Silicious* crystals are much prized in such as *quartz* or *rock crystal,* which is not very rare, and *precious stones* (rubies, sapphires, etc.).

11. The **diamond,** the most beautiful of all gems, is not a stone, it is pure and crystallised carbon.

12. Crystalline rocks (p. 123 and 126). — Crystals are sometimes agglomerated, forming stones and even rocks.

13. The **granite** upheaved from the bowels of the earth, is composed of three kinds of crystals : *quartz, felspar* (which gives *kaolin*), and *mica* (of which the so-called *gold powder* is made).

14. Porphyry, which is also of *igneous* origin, is composed of crystals of felspar set in a fine paste of felspar.

15. The **basalt,** of igneous origin, was projected from volcanoes, just as *lavas* are now thrown out of volcanoes still in action.

16. Metals and Coals (p. 127). — **Metals** are found underground, where they form *veins.*

17. Coal is the residue of immense forests buried during a prodigious number of centuries.

18. Peat is a sort of very young coal, as yet unburied.

19. Rocks (p. 129). — The limestones, the clays, the slates, the sandstones are not all mixed together. They are disposed more or less regularly in *layers* or *strata.*

20. These layers, with the fossils they contain, have allowed a classification of the different rocks or soils to be established.

21. In the first place we must distinguish : 1. the rocks of **igneous** (*ignis,* fire) origin; 2. the rocks of *aqueous* (*aqua,* water) origin.

22. The rocks of *igneous* origin have been formed by matter in fusion at a very high temperature, thrown up from the very depths of the earth. They comprise **granite, porphyries, basalts** and other **lavas.** — No fossils are found in them.

23. The rocks of *aqueous* origin have been deposited by the water of the **sea** and also by *fresh* water. We distinguish among them :

1. **Primary** rocks, above ancient *crystalline* rocks. At this period great forests that covered the ground, were submersed and slowly transformed into *coal.*

2. The **Secondary** rocks, superposed on the primary ones. In those days, the sea covered a great part of our country. Reptiles unknown at our epoch (ichthyosaurus and pterodactyle) have left their remains in the deposits then formed.

3. The **tertiary** rocks. In this period there lived a great number of mammalia very different from any existing at the present day.

4. The **quaternary** rocks, in which, for the first time, human remains or traces of man's industry are to be met with, remains that were deposited on the soil of our country long before history existed.

24. Movements of the soil (p. 131). — The ground is ever in motion, continually being upheaved here and sinking elsewhere, but so very slowly that the movement is altogether imperceptible.

25. Things have always been going on thus. Therefore the distribution of land and water on the surface of the globe has undergone many great modifications.

26. Under the influence of pressure exerted from within, analogous to that which gives rise to earthquakes at the present day, the bottom of the sea has been *upraised* in certain places, thrusting off in all directions, the water the uplifted bed could no longer contain. Elsewhere the soil that emerged from the waters sank down, and was covered over by the waves.

27. But what an immense length of time rolled by during these changes! Centuries that look so long, are but as minutes compared with these prodigious periods.

28. In our days similar phenomena take place on the coasts of Norway and Sweden : the Swedish coast is sinking, whilst that of Norway is rising; the Baltic is becoming more and more shallow.

29. Central heat and the crust of the globe (p. 141). — When a very deep hole is made in the earth, it has been remarked that the temperature gains at least one *degree* of heat every time the hole has been deepened 100 feet. So at the depth of 300,000 feet, the temperature would attain 3000 *degrees* centigrade. This is more than would be necessary to melt lava, porphyry, etc.

32. This leads to the conclusion that the whole earth is, internally, in a highly heated state, and that the comparatively cool crust upon which we dwell is, in proportion, much less than the thickness of an orange skin in regard to the orange.

SUBJECTS FOR COMPOSITION.

1st composition (p. 120). — Calcareous stones and silicious stones. — Action of acids on both. — Gypsum. — Slate.

2nd composition (p. 123). — Composition of arable ground.

3rd composition (p. 124). — Calcareous crystals and silicious crystals. — The diamond.

4th composition (p. 126). — Granite, porphyry. — Basalt.

5th composition (p. 127). — Metals. — Coal.

6th composition (p. 135). — Aqueous rocks and igneous rocks. — The order in which the former are superposed.

7th composition (p. 138). — Fossils to be found in the different strata.

8th composition (p. 130 and 142). — Movements of the ground. — Central heat and the crust of the earth. — Changes in the distribution of land and water.

THE PHYSICAL SCIENCES.

IV — PHYSICS.

108. We will, to day, begin the study of the **physical sciences**. Under this designation are comprised: *Physics*, *Chemistry*, and *Physiology*. These sciences are *very important*, extremely interesting and curious, and also very different from all we have hitherto studied.

As in the pursuit of these sciences experimental investigation is frequently necessary, they are also sometimes called **experimental sciences.**

109. Observations and Experiments. — The first thing I must explain is what is meant by the word experiment. See, here is a bit of wood. I throw it into the water. Thereby I ascertain that it floats; and the fact that it does so, leads me naturally to the conclusion that the bit of wood must be lighter than water. I then fix weights to it, and take note of the quantity I must add to make it sink and be as heavy as water: this is an *experiment*. Again, I put the wood in the fire, there you see it burns, gives off flame, smoke, and leaves charcoal: this also is an *experiment.*

110. Physical Experiments and Chemical Experiments. — The chip of wood I threw into the water a little while ago, once taken out and dried, regained its primitive condition, nothing was changed in its composition; this is an example of a *physical experiment*. But now that it is burned there are no means of restoring it to its original shape; and yet it has not disappeared, for were we to weigh the charcoal, the smoke and something else I will tell you about afterwards, we could find the exa[illegible]eight of the bit of wood; but the nature of the wood is totally changed: we have this time made a *chemical experiment.*

Now let me see if you have perfectly understood what I have been telling you. There, George, I have put some salt in this glass of water (fig. 1). What will be the result? The salt will melt away, Sir. Say rather it will *dissolve*, the expression is more correct. But, tell me, have I made a chemical or a physical experiment. A chemical experiment, Sir, as the salt has disappeared. No, my child, think again, the salt has not disappeared, *it has only changed its appearance.* The proof of this is, that the water has the taste of salt; moreover, if we pour the contents of the glass into a plate, and put the plate on the stone, the water will evaporate; when the evaporation is complete, you will find upon the plate *crystals of salt*, just as they were before the experiment.

Fig. 1. — The salt has not disappeared in the water; it has only changed its appearance, for it can be found again in evaporating the water (physical experiment).

Fig. 2. — Iron dissolved in sulphuric acid becomes another body : sulphate of iron, under the form of green crystals (chemical experiment).

Now here I show you a glass containing *oil of vitriol*, or as chemists say, *sulphuric acid*, into which I put in, as you see, a few bits of iron wire (fig. 2); some of these seem to dissolve as the salt did in the water. Only you see that the liquid instead of remaining colourless* as it was, becomes green. Then if you allow it to evaporate as in the preceding experiment, you will find that there remain not bits of iron, but beautiful green **crystals.** In this case the sulphuric acid and the iron have both disappeared, and a *new body* has been formed, which on account of its origin, chemists have called *sulphate of iron*, and others *green vitriol.*

1. To sum up what I have been telling you, I should say then, that physical experiments **make no alteration on the nature of bodies,** whilst chemical experiments **thoroughly modify them, and thereby give rise to new bodies.**

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1. What is the character of physical experiments ? — What is the character of chemical ones ?

I THE THREE FORMS BODIES ASSUME.

111. Solid, liquid, and gaseous forms. — **1.** You all know that there are **solid** as well as **liquid** bodies. A **solid** body is more or less hard or dense, and has a definite shape of its own; a **liquid** has no shape of its own, and is a fluid, that is to say, *it will flow away* unless enclosed in a vessel made of a solid body.

Bodies also assume another form, of which it is more difficult to give you an accurate idea; namely, **the gaseous** form. An experiment will afford you more enlightenment on the subject than a great many explanations. **2.** See here is an empty glass. Holding it upside down, I plunge it slowly into this other larger vessel, which is almost full of water (fig. 3). You see that the water does not fill the glass, and that above the level of the water, there is a space apparently empty. If you now incline the smaller glass to one side, a big bubble will escape, and the water will rise in the glass higher than before. What escaped in the bubble was air, or *gas which was* imprisoned under the glass, although like the air that surrounds us, it is invisible.

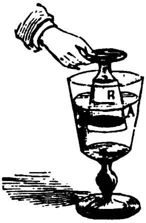

Fig. 3. — The water only mounts to A, the space B, is filled up with air, which is a gas.

Fig. 4. — The zinc first melts, then changes into gas.

3. *All bodies can successively assume three forms*: **solid, liquid,** and **gaseous. 4.** This is very evi-

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1. What are the three forms bodies assume? — 2. By what experiments can the existence of gas be easily proved? — 3. Can all bodies assume the three forms? — 4. Prove it, by taking water as an example.

dent in the case of water, which freezes into *ice* under the influence of cold, and evaporates in *steam* (or *gas*, which is the same thing) under the influence of heat. But this property is common to all bodies, only under a greater intensity of either cold or heat. **1.** Here is a bit of zinc that I have put in a shovel over the fire (fig. 4), see it rapidly becomes *liquid*, and were the heat strong enough it would soon disappear in *gaseous vapour*. Gases on the contrary are liquified, and liquids are solidified by *severe cold*. *Quite recently even air has been liquified and solidified.*

112. Evaporation and Ebullition. — The transformation of a liquid into a gas can be obtained by two different processes. **2.** Here are a few drops of water on a plate (fig. 5); in a short time they will have disappeared, and the plate will be dry: this is the result of *evaporation*.

3. So much for one process; let us now pass on to the other. Here is a pan full of water which I have hung over the fire (fig. 6). You can feel with your finger that the water is being heated; and you can also observe that the warmer it becomes, the greater is the quantity of steam given off. At last the water begins to boil; that is to say, it gives off *clouds of steam*. — After a while the water has all disappeared: this is *ebullition*. Thus *ebullition* is a forced and violent evaporation, instead of the slow

Fig. 5. — The water on the plate disappears *little by little* : *evaporation*.

Fig. 6. — The water in the pan gives off *clouds of steam* : ebullition.

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1. Now take some zinc. — 2. Give an example of the transformation of a liquid into a gas by evaporation. — 3. Give an example of the transformation of a liquid into a gas by ebullition.

and almost invisible process we observed in the first case.

113. Distillation. — Now look at this. **1.** Above the boiling pan I hold a cold plate (fig. 7). The steam on coming in contact with the plate *cools*, and as you see becomes *water* again. The water thus obtained is *perfectly pure, it is called* **distilled water,** *all its impurities have remained behind, in the pan.* **2.** The proof that distillation purifies water, is given by the fact that if you boil *salt water*, the product of the distillation of this salt water is *perfectly tasteless.* **3.** *Distillation* has then a twofold result. It first transforms liquids into vapours by heat; and these vapours are re-liquified by cooling.

114. Compressibility of gases. — A little while ago, in order to prove to you the existence of gas, I made a simple experiment which teaches us something very curious about the properties peculiar to gases. Let us then apply once more to our little glass, and invert it

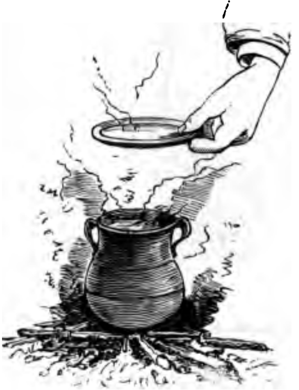

Fig. 7. — The vapour *condenses*, that is to say, becomes *water* again, on coming in contact with the cold plate: distillation.

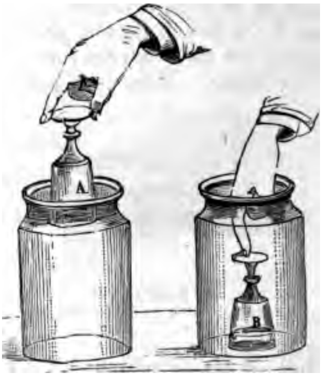

Fig. 8. — At the moment the glass touches the water, it is full of air A.

Fig. 9. — When the glass is at the bottom, the air is *compressed* at B.

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1. How is distilled water obtained? — **2.** Prove that a perfectly pure *water may be* obtained by distillation. — **3.** What are the two operations of distillation?

as before into a glass vessel full of water, pushing it straight and slowly to the very bottom. When the glass at first touched the surface of the water (fig. 8), you know it was full of air A; but now that I have pushed it down to the bottom (fig. 9), the air evidently occupies less space B.

1. This proves then that air can be easily **compressed.** **2**. On the other hand, when you withdraw the small glass from the water, the air it contained **expands** with equal facility.

115. Compressibility of liquids and solids. — All gases are, like atmospheric air, very easily compressed* and as easily expanded*. **3**. But it is altogether different in the case of liquids and of solids. **Extraordinary force** is required to compress *water*, and greater force still to compress *solids;* we may even say that they are **almost incompressible**. **4**. When people speak about compressed hay for instance, you must not imagine that it is the hay itself that is compressed, that would be impossible: the stalks of hay are merely pressed more closely together as the air that lay between them is expelled.

5. But feats that defy the most powerful machinery (namely the expansion and compression of liquids and solids), can be *most easily accomplished by a little* **heat** *or a little* **cold**.

II — HEAT.

116. Expansion of bodies. — **6**. When *heated*, solid, liquid, or gaseous bodies **expand;** that is to say, they occupy a greater space than before. **7**. Inversely, when cooled they **contract**.

Look (fig. 10) at the wheelwright when he puts an iron band round a wheel; he makes the iron ring slightly narrower than the circumference of the wheel, then puts

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1. What takes place when air is submitted to a pressure? — **2**. What happens to compressed air when submitted to relaxed pressure? — **3**. Can solids and liquids be as easily compressed? — **4**. What takes place when hay is compressed? — **5**. How can solids and liquids be easily compressed or expanded? — **6**. What is the effect of heat on solids, liquids or gases? — **7**. What is the effect of cold?

it into a large fire. **1**. The heat causes the ring to expand, so as to allow the wheel to be placed within it : then it is cooled, when the iron contracts and causes the ring to fit so tightly to the wheel that there is no need for nails to fix it This is a striking example of the application of *heat to solid bodies.*

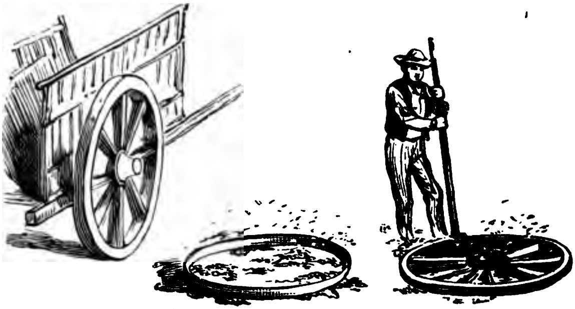

Fig. 10. — Cart wheel, with a band of iron round it.

Under the influence of heat, the iron band enlarges or *expands*.

In cooling, the band *contracts*.

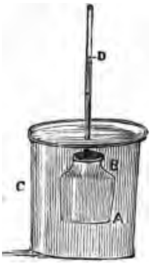

Fig. 11. — The bottle BA is placed in warm water; immediately the water in the tube mounts to D (expansion of liquids).

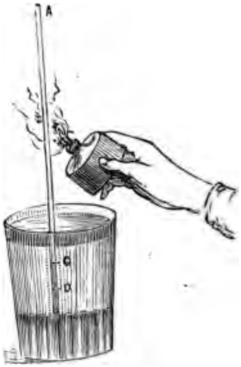

Fig. 12. — The tube being closed at A, the air in the interior *expands* under the influence of heat, and causes the water to descend from C to D (expansion of gas).

Here now I show you a small bottle BA (fig. 11) filled

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1. Give me an example showing the effect of heat on solid bodies.

with a coloured liquid; it is surmounted by a glass tube D, open at both ends, the liquid rises in the tube to a certain height. **1.** I immerse the bottle in a vessel C containing very warm water; immediately you can see the coloured liquid rise in the tube D by the effect of the *expansion* caused by heat.

Again, I put into a glass of water (fig. 12) a tube AD closed at the upper end A, open at the lower, and full of air: the water of the glass rises in the tube to a certain height C, which I mark with a stroke of a pen. **2.** This done, I apply to the upper part of the tube the heat of a spirit* lamp, immediately the water sinks in the tube, to D: why so? Because the *expanded gas* takes up more space.

117. Change in volume caused by change of form. — **3.** Heat is necessary to cause a body to pass from a *solid* to a *liquid* state; and still more heat is required to make it pass from a *liquid* to a *gaseous* state.

4. As heat brings about **expansion**, *a solid body will increase in volume by assuming a liquid form, and the volume will again increase in becoming gaseous.* — **5.** Inversely, a liquified* gas occupies less space under its new form; and this is generally the case when a liquid is solidified. **6. Water**, however, **is an exception** to this general rule; *its volume increases in becoming solid, in becoming ice.* **7.** And this is the reason why, when severe frost sets in, it is necessary to empty all reservoirs in which the water would be apt to freeze, else they would inevitably burst. The force thus developed is prodigious, for were a bomb* to be filled with water, the *expansion* produced, were the water to freeze, would rend it to pieces.

8. When stones are not very dense, and contain a certain quantity of water, this latter being liable to freeze in cold weather, they are often splintered and broken

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1. You have a tube half full of water, heat it; what will happen? — **2.** You have an empty tube closed at one end, plunge it into water by its open extremity, heat it, what will happen? — **3.** What must be done to cause a solid body to pass into a liquid state? From a liquid state into a gaseous state? — **4.** What is the consequence? — **5.** What are the inverse consequences? — **6.** Is it the same with water? — **7.** What precautions ought to be taken with reservoirs when winter arrives? — **8.** What is the effect of frost on stones that contain water?

to pieces. 1. From a similar cause, damp earth is raised up and crackled over during winter when there is no snow to cover it, just as the bark of trees is sometimes rent open.

118. Force of expansion of solids and liquids. — From what I have already told you, you may easily conceive that the force developed by bodies when they expand under the influence of heat, or when they contract under the influence of cold, is something extraordinary. I will endeavour to give you a still more accurate idea of this. You see this little iron rod I have in my hand; it is about 1/3 of an inch thick. If plunged in water at freezing point it would be ten inches long: in boiling water it would lengthen about the sixtieth part of an inch; this looks very insignificant indeed. Well, as insignificant as it is, if you wished to prevent this expansion, you would require to put upon the end of the rod a weight of 7500 pounds: you would never have fancied that I am sure. 2. Therefore when metals are used in buildings, *they must be arranged so as to have some working room*, otherwise the shortening and lengthening caused by the changes of temperature would dislocate the whole construction. So much for the force of cold and heat.

119. Temperature. — But what is cold, and what is heat? Ah! this is far from being easily understood. You must know however, in the first place, that heat and cold are not two different things: to cool a thing is not to add cold, it is to take away heat. When a thing is warmer than our body, or as we ought to say, when its *temperature* is higher than that of our body, we say, it is *warm;* if its heat is less, or rather if its temperature be lower than that of our body, we say it is *cold.*

120. Measures of temperature. — We can easily distinguish, by feeling with the hand, not only a cold body from a warm one, but also different degrees of heat and cold. Here are two vessels, in which I have made water boil; one has been taken from the fire five minutes ago, the other about a quarter of an hour

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1. *On the earth?* — On trees? — 2. *What precaution* ought to be taken in buildings against the expansion of metals?

since; dip your finger in both, you will feel that one is much hotter than the other. Here are two others, taken off the fire, one an hour ago, the other two hours ago; they have lost so much heat that both are cold, but the latter seems still colder than the former. It is then possible merely with one's hand to appreciate, by comparison and tolerably well, the temperature of bodies.

Only, as you can easily understand, this is not always sufficient. First, because one might be mistaken, further, how could the degree of heat be accurately expressed? This body is not so warm as that; but how much less? Is the body I touch at the present moment warmer or colder than the one I touched eight days ago? I have certainly quite forgotten. And yet were it necessary to know it, what could be done? Is it warmer to-day than it was this day last year. You do not remember, neither do I. For all that, it is sometimes very useful we should know such things.

121. Thermometers. — For this purpose instruments have been invented; and those instruments not only measure heat more accurately than the hand can do, they also give indications that can be kept in mind or noted down. **1.** The instruments I allude to, have been called **Thermometers** (from two Greek words *thermos*, heat, and *metron*, measure).

The first idea that presented itself was that heat might be measured by the *expansion* of bodies. Here is a bit of iron wire, it will lengthen slightly if I heat it in my hand; if I plunge it into boiling water, it will lengthen more; and still more if I put it in the fire. Were the value of these three changes to be measured, we would have the exact indications of the degree of heat given by the hand, the boiling water, and the fire; only these variations in length are not sufficiently perceptible, because the body acted upon is a solid.

Liquids expand to a much greater extent, and are besides more easily handled. They are therefore preferred for the construction of thermometers. It was a sort of thermometer we made, a little while ago, in our experiment with a glass tube full of liquid set in a bottle of water.

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1. What name is given to instruments that are used for measuring the temperature of bodies ?

But now we shall take a proper one, that has been made for that purpose alone (fig. 13). At the extremity of the tube of this real thermometer, we find (instead of a bottle, as we had in our experiment), a somewhat lengthened hollow bulb; instead of water it contains mercury*. The tube is fixed upon a board with numbered divisions. As we have no use for these divisions, I will separate the tube from the board.

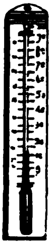

Fig. 13. — Thermometer with mercury mounted on a scale.

We must remark in the first place, the height of the mercury, and mark it A (fig. 14). Now I have plunged the tube into a glass of cold water, the mercury sinks down and stops at a point I mark B. I now take the bulb of the tube in my hand (fig. 15): the mercury immediately rises again, and stops still at a place I mark C. James, put the bulb in your mouth (fig. 16) : the mercury still rises, and comes to a stand at the spot I mark D. The distance between BA, AC, CD, indicates the differences of temperature that exists between the air, the glass of water, the palm of my hand, and James's mouth. The glass of water is colder, my hand and James's mouth are warmer.

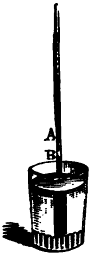

Fig. 14. — In cold water the mercury in the tube contracts and descends from A to B.

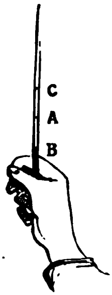

Fig. 15.—The heat of the hand causes the mercury to rise from B to C.

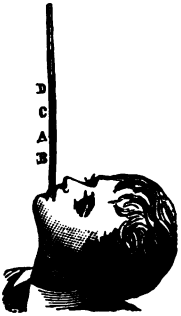

Fig. 16. — The heat of the mouth causes the mercury to rise from C to D.

George, in your turn, put the bulb of the thermometer in your mouth. Do not laugh, else you might break the tube. See the mercury rises, and stops short exactly at the same place as when it was in James's mouth; this proves that your mouth and his have the same temperature. Now take the bulb in your hand; ah! the mercury falls lower than the mark C, that signifies that your hand is colder than mine; but this is not astonishing as you have just taken it out of cold water.

122. Graduation of the thermometer. — We are now in possession of an instrument which will enable us to *compare* the temperature of bodies. Only were an accident to happen to our instrument, all our observations would be lost! Of course we could easily reconstruct another, only there would be no means of comparing the new with the broken one. So all previous observations would be worthless.

This then shows the necessity of marking off all thermometers in the same manner, so as to be able to *compare* them with one another. For this purpose, as you can easily understand, it was impossible to take the temperature of things at random. I will explain to you how this difficulty was overcome, and you will see that the plan, although a very simple one, has been the cause of new discoveries.

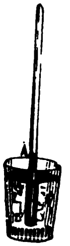

Fig. 17. — Thermometer plunged into *melting ice.* Temperature : 0°.

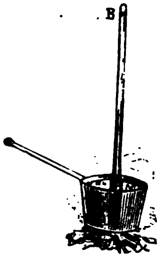

Fig. 18.—Thermometer immersed in *boiling water.* — Temperature : 100°.

Let us again take the thermometer we have separated from its scale. I have here a bit of ice, already half melted in the glass. Now plunge the bulb of my thermometer into the water of the *melting ice* (fig. 17). **1.** I see the mercury falls and stops still at a certain place A. Well, *all the time that the ice continues to melt, the mercury will remain at that very spot.* This is one **precise** spot easy to be found wherever a bit of ice is to be had. **2.** In the *centigrade thermometer*, used on the Continent

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1. If I plunge in melting ice the bulb of a thermometer with mercury in it, what will happen? — 2. In French thermometers what is called *zero*?

and often also in England for scientific *purposes, this precise and invariable spot corresponding to* **the temperature** *of* **MELTING ICE** *or* **FREEZING WATER** *is called* **Zero.**

1. I now put the bulb of the thermometer into boiling water (fig. 18), the mercury rises rapidly and stops at a certain place. I will mark this B. *All the time the water continues to boil the mercury will not move from this point.* This is another **precise** and invariable spot, quite as easily found as the first. **2**. In the centigrade thermometer this place corresponding to the **temperature of BOILING WATER** is marked by the number **100.**

3. The distance between 1 and 100 is then divided into one hundred equal parts (fig. 13). **4**. Each of which is called a **degree.**

Fahrenheit's thermometer is not divided in the **same** manner; the zero of its scale is 17 degrees centigrade at the freezing point, and the number 212 indicates boiling water.

As our thermometer is already graduated, were I to register it in the air, in cold water, in the hollow of my hand, in my mouth, we should find that the mercury stops successively at the numbers 15, 10, 25, 38. This shows us that the temperature of the air is 15 degrees (it is written thus 15°), that of water 10°, my hand 25°, and of my mouth 38°.

All these degrees *are above zero.* But in winter the column of mercury often falls *below* the freezing point, as the ice does not melt. Therefore equal divisions similar to those of the upper part are inscribed on the tube, marking the degrees *below the freezing point.*

We have now finished with the thermometer. But I have still something else to tell you about heat before leaving the subject.

123. Conduction. — George, put your hand into this basin of water that has been upon my table since morning (fig. 19). Is the water at the same tempera-

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1. I place in boiling water the tube of a thermometer with mercury in it. What happens? — 2. In centigrade thermometers what signifies the *mark 100°?* — 3. *In* how many parts is the tube divided between the 0° of melting ice, and the 100° of boiling water? — 4. What name is given to each of these parts?

ture as the air? — No, sir, it is colder. — Try with the thermometer. — The thermometer marks 15° in the air and in the water. — Then you see you were mistaken: the temperature of the basin of water is the same as that of the surrounding air, and yet the water seems colder. Put your hand on this marble slab, then on the table; the marble will seem to you colder than the wood, and yet it is not so. What can be the reason of this.

Fig. 19. — Water appears to you colder than air, because the water being a *good conductor* of heat, takes more of your own heat from you than the air does.

Fig. 20. — Charcoal being a bad conductor of heat does not burn my fingers, although the end is lighted A.

1. *The reason is, that the marble being a better conductor of heat than the wooden table, more heat is absorbed from your hand, and thus a greater sensation of cold is produced.*

2. Here is a bit of charcoal, lighted at one end, A (fig. 20). I can hold it in my hand, although my fingers are but a short distance from the burning part; yet it does not burn me in the least. Why? *Because charcoal is what is called a bad conductor of heat.* **3**. On the contrary, if I put into the fire one end of my iron tube (fig. 21), the whole tube becomes hot, and although it is nearly 10 inches long, I can scarcely keep my hand on the other end of it. And that is because *iron is a good conductor of heat*, for it allows heat to pass rapidly through its substance so as to reach my fingers.

To give you a striking example of the difference between a body that is a good conductor of heat and one that is a *non-conductor*, I will show you a very simple experiment. Here is a playing card (fig. 22) upon which

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1. Why do water and marble appear colder than the air, and wood? What name is given to this property in water and marble? — **2**. Give another example of a bad conductor of heat. — **3**. Give an example of a good conductor.

I have flattened a little bit of tin foil. I hold the card above a gas burner or over a small lamp. See the tin paper melts, and yet the card does not take fire. **1.** *The tin, a good conductor, absorbs all the heat, whilst the card, a non-conductor, does not keep enough to take fire.*

Fig. 21. — I can scarcely hold my iron tube, it is so hot : iron is a *good conductor* of heat.

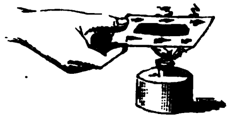

Fig. 22. — The card being a *non-conductor* of heat does not retain enough heat to set it on fire. While the tin being a *good conductor* absorbs all the heat and melts.

2. Metals *are very good conductors; stones* are less good, and *wood* still less. **3. Air** itself is a *non-conductor*. Therefore our clothes preserve us from cold for two reasons. **4.** In the first place they are composed of fibres of cotton, of hemp, of flax, or threads of wool or silk, all of which are *non-conductors* of heat. Further and above all, between the filaments of each tissue, and between the differents parts of our clothing, there is a certain quantity of air: this air is but slowly heated; only when it is once heated it remains so, thus protecting us from outward cold.

Water being a better conductor of heat than air is, you can understand why you felt it cold when you plunged your hand therein. But once your hand was withdrawn from the water, did it get warm again immediately? — No, sir, *I think I felt it colder than when in the water.* — Ah! that also demands an explanation.

124. Heat absorbed in evaporation. — 5. I showed you a few minutes ago *that in boiling water, and during all the time it boils, the thermometer indicates the temperature of* 100° *centigrade;* in other words, the temperature remains constant. And yet we

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1. What takes place in the card experiment? — 2. What do you know of the conductibility of metals, *stones and* wood? — 3. Of air? — 4. Why do our clothes protect us from the cold? — 5. What is the temperature of boiling water in an uncovered saucepan?

added heat, for the fire continued burning under the pan. What became of all this heat?

This is not easily understood. **1.** All I can say upon the subject *is that this heat has been employed to make steam;* the proof of this is, that if you prevent the formation of steam, by hermetically closing the pan, the temperature of the water goes beyond 100°. Now do not forget this : *in order to produce vapour, in other words, to transform a liquid into a gas,* **heat is necessary.** **2.** There was water on your hand a little while ago; and to dry that water, to allow it to become gas, heat was required. Where was this necessary heat to be found? *In your hand,* which in consequence was cooled.

And where does all this vapour go? Into the air But it is not visible. No, because it is quite transparent, nevertheless it exists. Here is a bottle just brought from a cool cellar (fig. 23). The vapour of the air has *condensed* upon the bottle in minute drops of water. Where does this water come from? Not from the inside of the bottle I should fancy. **3.** No, from without, from *the air:* it was then in the state of vapour; and as the bottle was colder than the surrounding air, the vapour became water by contact with the bottle, or as we should say, it *condensed.* It is also *distilled* water. But wait till the bottle is at the same temperature as the air of the room, the misty appearance will pass away, the water will have once more *evaporated.*

Fig. 23. — The vapour of the air is *condensed* on the bottle in drops of water.

125. Power of boiling Water. — I have just told you that if in heating water, you prevent the formation of steam, the heat of the water goes beyond 100°. **4.** *The simplest way of preventing the formation of vapour is to heat the water in tightly* **closed** *vessels.* But the vessel must be very strong indeed, else it

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1. Seeing that the fire continues heating the saucepan, what becomes of the heat? — Prove that heat is employed in making steam. — 2. Why is a sensation of cold felt, when a wet hand is dried in the air? — 3. Why is a bottle that has been brought up from the cellar, covered with vapour? — 4. By what means is the vapour or steam prevented from forming?

would soon be shivered in pieces. **1.** ***For the vapour of boiling water has prodigious force.*** **I have here a tube of zinc A (fig. 24) which contains a little water, and which is well corked. I hold it with the tongs over the fire. The water of the tube soon reaches the boiling point, and this is no sooner attained than the cork is violently expelled with a loud report.**

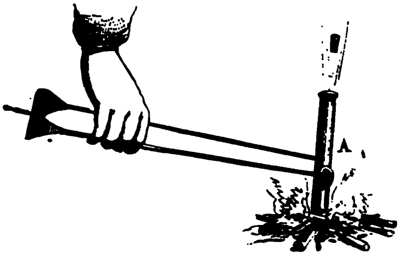

Fig. 24. — The force of the vapour imprisoned in the tube A causes the cork to fly out.

If, instead of corking the tube, I had shut it with a lid, closely fitted and firmly fixed, the temperature of the water would have increased, and the steam would have then acquired great force, and in a short time the tube would have been shivered to pieces.

When water in a closed vessel, reaches a temperature of about 121 degrees centigrade, the pressure of the steam generated is equal to that of 30 pounds on the square inch.

2. It is upon this principle that ***steam engines*** act. The water is made to boil in closed tubes, in which the steam produced acquires enormous force. This steam is then allowed to escape in a certain direction, and can according to circumstances lift great weights, or put into action great wheels, etc. In another course of lessons we shall further speak of this admirable invention.

SUMMARY. — HEAT.

1. *Physical* experiments produce no alterations in the nature of bodies; *chemical* experiments totally change it, and give rise to new bodies.

2. The three states of bodies (p. 148). — There exist *solid* bodies, *liquid* bodies, and *gaseous* bodies.

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1. What property does the steam *of boiling* water possess? — 2. Name **an admirable invention that results from this property.**

A pebble is a solid body, — water a liquid body — air a gaseous body.

3. Most bodies can successively pass through these three states. Thus ice (solid) becomes water (liquid), then steam (gas).

Another example : Zinc, which is a solid metal, becomes *liquid* by melting over the fire, and is changed into a gaseous *vapour* if the fire be very strong.

4. Evaporation, ebullition, distillation (p. 149). — The rain that wets the highway is dried by *evaporation*.

5. The water that boils in the kettle sends forth vapour by *ebullition*. — So ebullition is very rapid evaporation.

6. The water obtained by cooling steam is *distilled* water.

7. Compression and expansion (p. 150). — It is said that a body is *compressed* when it is forced to occupy less space.

8. A body is said to *expand* when it occupies greater space than it did before.

9. *Gases* are very easily compressed and *expanded*; liquids and solids are almost *incompressible* by ordinary means.

10. Expansion and contraction (p. 151). — What the most powerful machinery is unable to do, namely to *compress* or *expand* water or iron; **heat** and **cold** can accomplish with the utmost facility.

11. When a solid, liquid, or gaseous body is **heated it expands.**

12. When it is **cooled** it **contracts.**

13. Gas occupies less space when it becomes liquid : and generally liquid occupies in like manner less space in becoming solid.

14. Water is an exception, its volume increases in becoming **ice.** This is the reason why in winter pipes and reservoirs burst, and some stones break from the same cause.

15. Thermometers (p. 155). — One can measure the *temperature* of a body, that is to say, its degree of heat or of cold, with the help of a **thermometer.**

16. The invention of thermometers depends upon the property liquids possess of *contracting* under the influence of *cold*, and *expanding* under the influence of *heat*.

17. In the centigrade thermometer, the temperature of **melting ice** is marked by 0.

18. The temperature of **boiling water**, in the same system, is marked 100.

19. The interval is divided into 100 *divisions* called **degrees.**

20. Bodies conductors of heat and bodies non-conductors (p. 158). — Heat passes through the substance of bodies with greater or less facility.

21. Some, such as iron and other metals, conduct heat with great ease; these are called *good conductors*.

22. Others, such as air, wood, charcoal, conduct it with less facility : these bodies are said to be *bad conductors*.

23. Water made to boil in tightly closed vessels acquires a very high temperature, and gives origin to steam having very great power. This power is utilised in steam engines.

III — LIGHT.

126. Luminous rays. — Where does *heat* come from, George? — From the fire, Sir. — Yes, in a room, but outside? — Ah! outside, from the sun. — Very well, but do the fire and the sun give heat only? — No! they also give *light*. — Perfectly so. Well, **as *heat always accompanies light*, it will be easier to see how heat proceeds in examining it with the help of light: for it is easier to follow out an observation with one's eye than with a thermometer. 1. In the first place, light always moves in a straight line.** See, in the schoolroom, the sun is striking directly on the closed shutters (fig. 25). Only as there are holes in the shutters you can observe that from each hole there starts a luminous line in which dance myriads of tiny specks of dust. **2. Place your hand in one of those lines, and you will have a sensation of warmth. This proves once more that *heat* accompanies light.**

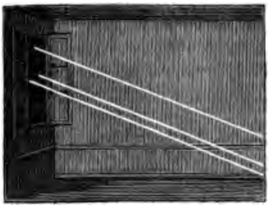

Fig. 25. — Light travels in a straight line.

127. Dark room. — But this leads me to show you a very curious phenomenon. Paul, go into the dark room and place a sheet of white cardboard C (fig. 26), on the line of yonder sunbeam A*a*, B*b*, etc. that shines through the hole of the shutter. **Look. All the objects outside are distinctly figured upon the** pasteboard. Here is the pond beside James's house, and the highway with a carriage on it; **only on the card-**

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1. How does light travel? — 2. What is it that always accompanies *light?*

board every thing is seen upside down. Strange as this may appear, it is very easily explained.

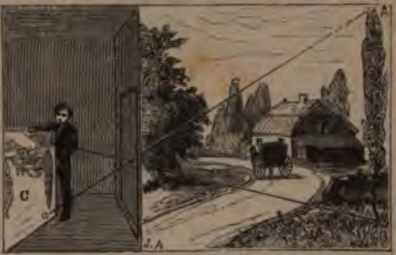

Fig. 26. — The objects outside are distinctly figured on the cardboard C, only they are upside down.

From the top A of the poplar tree, for instance, luminous rays start off in all directions; but one only can pass through the little hole, so as to reach the cardboard, at the point *a*. From the foot of the tree another ray can penetrate and reach the point *b*. It is the same with all the points situated between *a* and *b*. So the poplar is seen figured head downwards. The same thing happens, as you can easily understand, at all the other points of the landscape.

128. Velocity of light. — Light moves with extraordinary velocity. **1.** It travels at the rate of 185,157 *miles in a second;* it requires but about the seventh part of a second to go all round the world, and is only eight minutes in coming from the sun to the earth.

129. Reflection of light. — Now be very attentive. I hold, so as to catch the sun's rays, a small mirror (fig. 27). **2.** You can see on the walls of the school

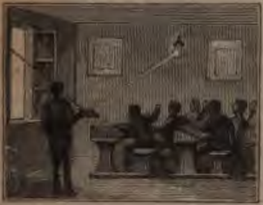

Fig. 27. — The light is sent back on the wall, at A by the looking glass (reflection).

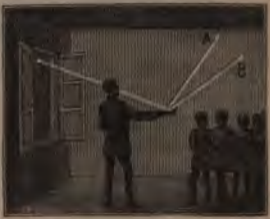

Fig. 28. — There is a direct relation between the direction of the ray received, and the reflected ray A and B.

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1. How fast does light travel? — 2. I receive the sun's rays on a small ooking-glass; what takes place?

room, a luminous spot A make its appearance. If I move the mirror, the spot moves likewise.

This spot is formed by the sunlight falling upon the mirror, and then starting off again; it is said to be **reflected**. Let us go into the dark room (fig. 28), and then catch upon the mirror the sunbeam that passes through the hole *r* of the shutter. It is reflected, tracing a radiant line in the dust of the air, and reaches the wall at A when I hold the mirror about straight; if I slightly incline the mirror, the reflected ray reaches the wall at B. There is, then, *direct relation between the direction of the ray that falls on the mirror and that of the reflected ray.* We will by and by learn to measure the value of this relation.

This will explain to us how a mirror shows us our image when we stand in front of it; how our image (fig. 29) seems to be placed at the same distance behind the mirror as that which separates us from it, so that savages never fail to seek behind the mirror the image they see in it; how it is also that the image is turned in the opposite way, so that the right hand seems to be the left, and *vice versa*. Only in order to understand all this properly, some notions of geometry are necessary; therefore we will wait until those are acquired before proceeding farther in this direction.

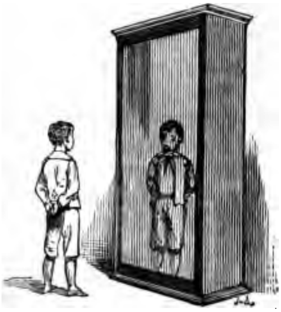

Fig. 29. — Looking-glasses reflect objects (reflection).

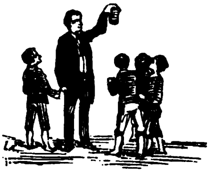

Fig. 30. — The surface of the water reflects objects underneath as the mirror does.

The mirror I used a few minutes ago is a common tinned * glass; but some are made in polished metal. All smooth brilliant surfaces can serve as mirrors. Here is a glass of water (fig. 30). See, I hold it a little above my eye, so as to look at the surface of the water from below.

It appears to me like a plate of polished silver; look at it yourselves : you may see all the surrounding objects reflected in it just as you would see them in a real mirror.

1. This will do for the present. We will now pass from this subject, namely the *reflection of light,* to **refraction.**

130. Refraction of light. — *Refraction* is a word that means *breaking.* You will see that the word is perfectly suitable. **2.** See. I have here a glass of water, and into it I plunge obliquely a bit of straw (fig. 31) : the straw appears to you as if it were **broken,** and looks to be more horizontally directed immediately on entering into the water. You know very well that the straw is not broken, yet you can scarcely keep yourselves from thinking that it is so.

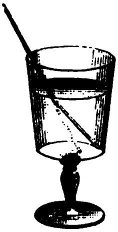

Fig. 31. — The bit of straw appears to be broken in the water (refraction).

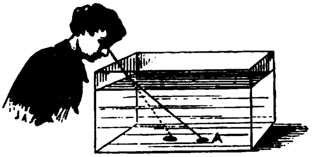

Fig. 32. — The luminous ray is broken on entering the water, and causes the penny to be seen at A in advance of the spot where it actually is (refraction).

And again another experiment will lead us to a similar conclusion. I have prepared for the purpose (fig. 32) a tin box, and put a penny in the bottom. Come here, James, and stand so as to be able to see only the further edge of the penny. There now, I pour water into the box slowly and carefully so as to avoid displacing the penny. Tell me what you see? I see the penny apparently rise and move forward towards A. This happens because the rays of light from the penny are *deviated* or seem to be *bent,* just like the bit of straw a little while ago.

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1. What name is given to this property of light falling indirectly on the looking glass? — 2. What happens if I plunge obliquely a bit of straw into a glass of water?

1. This is what is called **refraction.** **2.** It takes place every time a ray of light **passes obliquely from a transparent medium,** of one density, to that of another density, the ray being bent in one direction when entering a denser medium, and in another when entering a rarer medium. Flat glass influences a ray of light in the same manner that water does.

I put flat upon this book, a bit of thick glass (fig. 33). You can see that the lines appear deviated, as the straw did.

If I hold the bit of glass at some distance from the book (fig. 34), the deflection or swerve of the lines this time indicates two refractions. The first takes place when the rays of light that come from the book pass from the air into the glass; the second when they repass from the glass into the air.

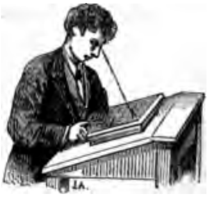

Fig. 33. — The lines of the book, in passing from the glass into the air, appear deviated : simple refraction.

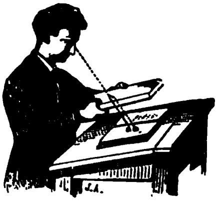

Fig. 34. — The rays leave the book deviate in passing : 1. from the air in the glass; 2. from the glass into the air : double refraction.

131. Lens. — When a piece of glass is not flat on both sides, the deviations are much more complicated.

Paul, what name is given to this bit of glass A (fig. 35) convex on both sides? — It is a *magnifying glass.* — So it is, **3.** but the scientific name given to it is *Lens.*

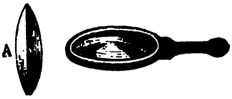

Fig. 35. — Double *convex* lens (rounded on both sides).

4. It is used, as its common name, magnifying glass, indicates to *magnify small objects.* Take this one in your hand, and look at the very fine print of this book. Well, what makes you look so astonished? — Why, Sir, because I see nothing at all. — Have a little patience : you must neither put the

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¶ 1. What name is given to this phenomenon? — 2. When is refraction *produced*? — 3. What name is given to a piece of glass convex on both sides? — 4. What are *magnifying glasses* or *lens used* for?

lens close to your eye, nor your nose close to the book. Look as you generally do, only through the magnifying glass, holding it at first close to the book. Now lift it slowly upwards (fig. 36), while you still keep looking through it. There now, the letters *seem larger*. Continue to remove the glass; they grow bigger still, and become quite distinct. If you still continue lifting the glass farther away, you will see them grow dim and finally disappear. 1. So the proper distance must be found out, *and the stronger the lens the shorter this distance is*. The lens you are using about doubles the size of things, and must be held at about an inch from the object looked at.

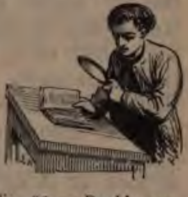

Fig. 36. — Double convex lenses magnify objects.

132. Compound magnifying glasses and microscopes. — When **several lenses** are arranged together according to certain rules, stronger magnifying power is attained, giving sometimes ten or twelve times the real size : this is what is called *a compound magnifying glass*. Again microscopes are made by still more complicated arrangements of lenses. **Microscope** (fig. 37), comes from two Greek words *micros*, small, and *scopeo*, to look at.

Great magnifying power may be obtained by a microscope. Things appear 100 times, 200, and even 1000 times larger than they really are. I see that this does not astonish you very much, because a quack at the fair declared that he could show things a million times greater than their real size. But this depends on the way of counting. When I say that my microscope magnifies ten times, I mean

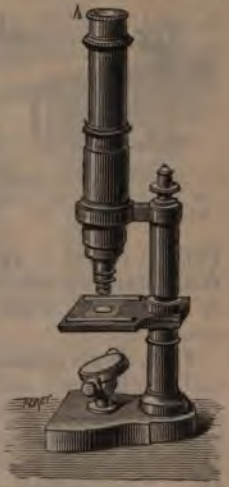

Fig. 37. — The microscope magnifies still more.

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1. What must be done in order to clearly distinguish an object with a lens?

that an object the tenth of an inch long, seems to be a whole inch long. The charlatans do not count in this way. As a thing is magnified not only in length, but in width and in thickness, they multiply three times, and so they would say that my magnifying glass magnifies 10×10×10=1000 times. Thus counted the showman's million becomes simply a 100. Only that would have made less fuss, and would have less amazed ignorant people.

Nothing is more instructive nor more amusing than to look at things with a magnifying glass. I could not tell you all that you might see in examining *insects, flowers,* in fact everything around you, your own *skin,* your *clothes,* etc., with a two shilling magnifying glass.

1. Had we time, how many astonishing and marvellous things might I not show with its help. ***Thousands of living beings in a drop of stagnant water, millions of tiny red bodies in a drop of blood,*** and I cannot tell what besides.

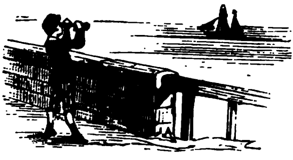

Fig. 38. — Telescopes magnify objects in the distance, and consequently make them appear near.

133. Telescopes and spyglasses. — A sort of microscope for magnifying things at a distance so as to make them look near, is made by *arranging different* lenses in another way. This is called a **spyglass** or a **Telescope** (fig. 38). With its help we can study even the stars, and see in them many details absolutely invisible to the naked eye.

134. Eye glasses or spectacles. — There is still another and well-known kind of magnifying glass, namely *eye glasses* or *spectacles;* these are small oval bits of glass that people having bad sight put before their eyes. I am obliged to wear them because I am old; here they are. You see they are simple *lenses* that magnify but slightly: take them in your hand, use them like a magnifying glass and see if you can read with them.

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1. With the help of a microscope what can be discovered in a drop of *stagnant water?* — In a drop of blood?

I see Henry shakes his head. Ah! I see why. I am not the only person in the school who wears glasses; James, although young, is obliged to use them, and Henry finds that James's glasses cannot be used as a magnifying glass. He is quite right too, and I will explain to you why.

1. You must *know that* there are not only *convex* lenses, but also *concave* ones (fig. 39). **2**. Now concave lenses instead of magnifying things, lessen them; instead of making objects look nearer than they are, they make them appear farther off.

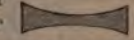

Fig. 39. Double *concave* lens (hollow on both sides).

Come here beside me, James, and bring your book along with you, only take off your spectacles; I have put mine aside also. And you, Henry, who have good eyes, come and stand beside us. Let us try to read at the same time, each in a book with the same sized print. Now that I have not the help of my spectacles, you see, I am obliged to hold my book at arm's length (fig. 40), before I can distinctly discern the letters; James, on the contrary, puts his close under his nose; while Henry holds his at a reasonable distance, about 8 inches from his eyes. This is because **3**. Henry has good sight, James has short sight, or *myopia*, and

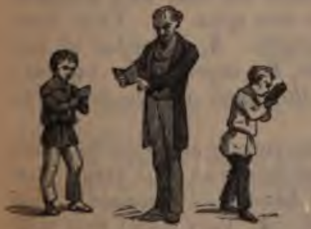

Fig. 40. — Henry has good sight, I am *long sighted*, and James is *near sighted*.

Fig. 41. — We have put on our spectacles : our bad sight is cured.

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1. What name is given to a lens, slightly rounded on both sides? — What name is given to a lens that is a little hollowed on both sides? — 2. What is the effect produced by a *concave* lens? — 3. What kind o sight are those persons said to have, who see objects near, but not far off? — Those who see far, but not near?

I have long sight. We will now put on our glasses again. Ah! that is right; we all three hold our book in the same manner (fig. 41). Our bad sight is cured. I will give you the explanation of this fact, when we study *Physiology*.

Now let us leave aside the lenses that *lessen*, and that are only useful to short-sighted persons, and return to *magnifying lenses*. Until now we have used them for looking directly at things, by holding them between our eye and the object we desired to see. We can use them also for another purpose.

135. Focus of a lens. — Look! this time I hold my lens right in the sun (fig. 42). Behind it I place a sheet of paper, towards which I gradually bring the lens. **1.** You see at a certain distance a *white spot* A *appears upon the paper;* this spot lessens as the lens comes nearer, until it becomes only a *speck* in size, but is excessively brilliant and luminous. And no wonder, *for all the sun's rays that fall upon the lens are brought together in this spot.* **2.** This spot is called the **focus** of the lens. **3.** In order to use the lens as a magnifying glass, *the object to be magnified must be placed between the focus and the lens.* Do not forget this.

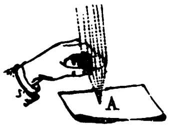

Fig. 42. — All the luminous rays are brought together at the point A, called the *focus*.

James come here and hold out your hand above the sheet of paper, (fig. 43), see the focus shines on your skin. But why do you draw away your hand? — Because I feel the bright spot to be *very hot.* **4.** Very well; that will help you to keep in mind *that* **heat** *always accompanies light, and that the calorific focus is at the same point as the luminous focus.*

The larger the lens is, the greater is the quantity of sunlight it gathers together and concentrates, and the more luminous and hot is the focal point. **5.** With this

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1. What happens when a lens is placed above a piece of paper, so as to attract the sun's rays? — **2.** What is that point called where all the sun's rays meet? — **3.** When a lens is used as *a magnifying glass* where ought we to place the object we wish to magnify? — **4.** What is it that is called the *calorific focus* of a lens? — **5.** What experiment can be made with a lens and some tinder?

little lens, I can easily set fire to tinder (fig. 44). But to obtain this result it is not necessary that the lens be of *glass*, all *transparent* bodies will answer the same purpose. Ice for instance, being a transparent body. **1.**

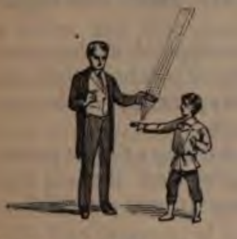

Fig. 43. — At the *focus* A, on your hand, all the rays of *light*, are brought together.

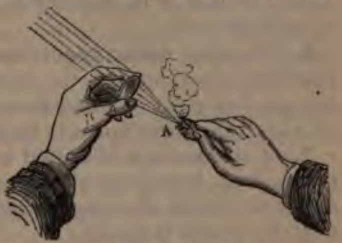

Fig. 44. — At the focus A of my little lens, all the rays of heat are brought together, and light tinder.

Navigators at the North Pole have been able to kindle fire with the pale rays of the arctic sun concentrated by a large lens hewed out of a block of ice. Great of course was the amazement of the Esquimaux at this sight, and equally great was the surprise of the sailors.

Colours.

We come now to a very important and most interesting experiment.

136. Dispersion of light. Solar spectrum. — Here is a crystal stopper, cut with six faces (fig. 45). I turn it in the sunlight, above this sheet of paper. When in a certain position, it casts on the paper a *many-coloured spot.* If we look attentively at this spot we shall see that in the middle, it is bright *green* and *yellow*, on the one side *red*, on the other *blue and violet.* You all recognise the colours of the **rainbow. 2.** It is said they are **seven** in number: these seven are, if we begin by the vio-

Fig. 45. — The block of cut glass divides the solar light into seven colours; *violet indigo, blue, green, yellow, orange, red.* The combination of these colours is called a *spectrum.*

---

1. By what means can a fire be kindled with ice? — 1. In how many colours is the solar light divided? — What are these seven colours?

let side (which is the lowest in the rainbow), **violet, indigo, blue, green, yellow, orange, and red.**

But in reality there are a great many shades running into each other and blending together, from the red to the violet, so that it is impossible to tell where one begins or another ends.

1. The term **solar spectrum**, is applied to this combination of colours of the miniature rainbow that our stopper has given us; and that of **dispersion**, to the way in which the light spreads itself out.

2. *A spectrum is obtained when a ray of light passes through a transparent body, provided the surface through which the ray penetrates is not parallel to that by which it issues.*

3. This shows that *all the colours are contained in the sunlight, although it is apparently white* and *colourless.*

137. Recomposition of white light. — We shall have a proof of this by a very simple experiment. Here is a round bit of cardboard, upon which I have painted all the colours of the rainbow (fig. 46). The cardboard has a little hole in the centre, into which I introduce a rod. I then rapidly whirl the card round the rod as round an axle.

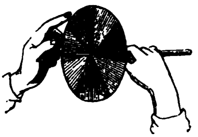

Fig. 46. — The *white* light is produced by the *union* of the seven colours of the spectrum.

4. *You see the colours disappear, and the cardboard becomes almost white.*

It was not even necessary to paint the *seven* principal colours on the cardboard, *three* were sufficient : red, yellow, and blue. The reason of this is, that the other colours, orange, green and violet, can be produced by the blending of the three others, two by two. **5.** See : here is another bit of cardboard, painted half *red*, half *blue*. If I make it whirl

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1. What name is given to all these colours taken together? — What name is given to the phenomenon of a ray being divided into seven colours? — 2. How can a spectrum be obtained? — 3. What conclusion may we draw from the formation of a solar spectrum? — 4. What colour does a card assume when painted with the seven colours of the spectrum, and turned round rapidly? — 5. What colour does a card half red, half blue appear to be while turning round? — Half red, half yellow? — Half yellow, half blue?

round like the first piece, it will appear **violet**; and this other, half *red*, half *yellow* will appear **orange**; lastly, this one, *yellow* and *blue* will look **green**.

138. The colour of objects. — But what does it imply when we say that this cardboard, or anything else is white, and that green or red or black. [1] It means, that the white *cardboard or any other white object, reflects all the light it receives, and keeps back or absorbs nothing; blue or red absorbs all it receives excepting the blue or red part of the ray; the black absorbs all, and reflects nothing.* What is the reason of this? Ah! I am at a loss to explain it, so you must content yourselves with the mere knowledge of the fact.

In like manner, if water is white, wine red, ink black, it is because water lets the whole ray of light traverse it, whilst the red part alone passes through the wine, and the ink absorbs all.

There are then two sorts of colours, colours given by *reflection*, as is the case with the sheets of cardboard; colours given by *transparency*, as is the case with coloured liquids or coloured gases, or transparent solid bodies, like glass.

Certain bodies have not the same colour when seen by reflection or by transparency. This very thin sheet of beaten gold leaf for instance, looks quite *yellow* when the light shines upon it, yet if you look at it when placed bettween you and the light it will seem to be *green*. Such instances are however rare.

SUMMARY. — LIGHT.

1. **Propagation and Rapidity** (p. 164). — Light travels in a *straight line*.

2. It travels at the rate of 185,157 miles per second.

3. **Reflection** (p. 165). — When a luminous ray falls upon a mirror, it is *reflected*, that is to say **thrown back** according to a given angle, and projects a brillant spot upon the wall. This phenomenon is called **reflection**.

4. **Refraction** (p. 167). — A body partially immersed in water looks as if it were *broken*, this is the effect of the deviation of luminous rays. This phenomenon is called **refraction**.

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[1] What is meant when it is said that the colour of an object is white? — Blue or red? — Or black?

5. Refraction is to be observed every time a luminous ray passes obliquely from one transparent body to another equally transparent, but of unequal density.

6. Lenses (p. 168). — A *lens* is a bit of glass which has one or both of its sides concave or convex : there are *convex* lenses, that enlarge the object, and *hollowed* or *concave* lenses, that lessen objects.

7. *Magnifying glasses* cause things to look larger, and are made with a convex lens.

8. *Microscopes* are formed by a number of lenses disposed according to known rules in such a manner as to greatly magnify the dimensions of things quite near.

9. A **telescope** is formed by several lenses disposed so as to magnify distant objects.

10. *Spectacles* when intended for near-sighted persons are formed by hollowed or concave lenses; those destined for long-sighted persons are formed of convex lenses.

11. The rays of sunlight that fall upon a convex lens come together beyond the lens at a point called the **focus.**

12. As heat always accompanies light, rays of heat also concentrate at the luminous focus.

13. Dispersion, the solar spectrum (p. 173). — When a ray of light passes through a transparent body, through two plain but not parallel faces, it spreads itself out, or *diffuses itself*, and produces a sort of *coloured band*, in which the **seven colours** of the rainbow may be recognised. This coloured spot is known by the name of *solar spectrum.*

14. The seven colours of the spectrum are disposed in the following order, if we begin with the under part of the rainbow : *violet, indigo, blue, green, yellow, orange, red.*

15. These seven colours united, form **white light.**

16. *Coloured bodies* enjoy the property of reflecting or allowing to pass through them only a part of the colours, composing white light. Thus a *blue* object absorbs six of the seven colours, and reflects the *blue.*

[At page 232 subjects of composition are given.]

IV — SOUND.

We detect and appreciate heat on the whole surface of the skin; light by the eye; and sound by the ear. We already know whence come heat and light, how they move, and how they act. Let us now learn something about **sound.**

1. *Sound is always produced by the shock of two*

---

1. How is sound produced?

bodies. If struck even slightly some bodies give sound: like this wine glass, this metal lid, this tightened fiddle string. **1**. Such objects are called *sonorous bodies*.

159. Sonorous vibrations. — Paul, come near me; I have struck this wineglass with a rod: it gives a strong and clear sound. Put your finger on the edge (fig. 47), what happens? — The sound ceases. — Yes, but what did you feel with your finger? See, there I strike again. — **2**. Ah! Sir, I feel *the glass tremble while it rings; when I stop the trembling, the sound ceases*. **3**. It is said that the glass **vibrates**, and it is those *vibrations which produce sound*.

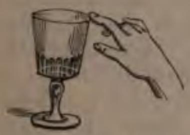

Fig. 47. — Sound can be produced by the vibrations of glass. When the vibrations are checked, the sound ceases.

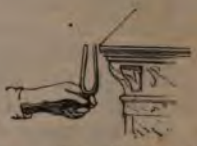

Fig. 48. — The vibrations of the tuning fork are visible. If you stop them, the instrument is silent.

Strike this tuning fork* (fig. 48): its vibrations are quite visible; and when you check them, the instrument becomes silent. So is it also with this lid, only you cannot perceive its vibrations.

Now the glass and the tuning fork are not in contact with our ear, how is it that we can hear their vibrations? **4**. We hear them because *they are transmitted to the air, which vibrates in its turn, and thus communicates vibrations to the interior of our ear*.

If any thing in my explanations puzzles or embarrasses you, you must tell me. Have you any thing to say, George?

— Yes, Sir! When a gun is fired, it makes a great noise, yet nothing has been struck, nothing vibrates. — You are mistaken there, my child, the *air vibrates*. The gunpowder on taking fire produced an enormous quantity of gas, which having vent only by the barrel

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1. What name is given to bodies that produce sound at the least shock? — **2**. What is felt on putting the finger on a glass that has just been struck? What happens when you stop the vibrating of a glass? — **3**. What name is given to this phenomenon? — **4**. How is it that we hear the vibrations of a body that does not touch our ear?

8.

of the gun, bursts out with extraordinary force. And this gas, when it violently struck the air, set it *in vibration*: thence the *sound.*

I will give you a proof that *sound is brought to us by air.* George, go into the yard, before the open window, and strike those two sticks gently on one another. You can all hear the sound? Now shut the window : the sound can be no longer heard. A thin pane of glass is sufficient to keep the sound from coming to us; it has prevented the vibrations of the air from reaching our ears.

But had the vibrations been strong enough, their energy would have reached the panes, and have caused them to vibrate also; they in their turn would have transmitted their vibrations to the schoolroom air, and so the sound from without would have reached our ears. Closed windows do not keep us from hearing many disagreeable noises, for example, that made two hundred yards off by our good friend Thomas the coppersmith, as he hammers on his pots and pans. Besides, I am sure you have all heard the panes vibrate under the influence of a loud noise quite near.

140. Rapidity of sound. — *Sound does not travel very rapidly through air.* Open the window again. Thomas is making a great noise in mending the boiler of a steam engine (fig. 49)*. Look, and listen attentively. Do you remark anything in particular? — Sir, when I see Thomas strike his boiler I hear nothing, and it is only when his hammer is as high as it can be that I hear the sound of the blow. And yet of course it is when he strikes that he makes noise. The sound you hear when the hammer is uplifted, *is the* sound of the blow he struck an instant before.

Fig. 49. — The sound is heard *after* the hammer has been seen to strike.

Why this difference of time? **1.** *Because light travels with astounding rapidity, you see the movement that Thomas makes, at the moment he makes it, while, as sound travels much more slowly, it reaches you rather later.*

The next time you find an occasion, observe a sportsman fire his gun (fig. 50). *You will see the white cloud of smoke come out of the barrel some seconds before you hear the report;* and the greater the distance between the sportsman and you, the greater will be the difference between the moment you see the smoke and the moment you hear the sound. It is by calculating this difference between time and distance, that people are able to measure the rapidity of the propagation of sound through air.

Fig. 50. — The smoke is *seen before* the report of the gun is heard.

2. It has been ascertained that sound travels at the rate of 1125 feet per second.

141. Transmission of sound by solids and by liquids. — I have already told you that it is by *air* that sound is generally borne to us. **3.** But sonorous vibrations can be transmitted to us by *liquids* and even by *solid bodies*. Put your ear to the end of this long table (fig. 51); although I touch the other end very gently, you can distinctly hear the sound.

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1. The coppersmith strikes a boiler in the distance. Why do you see the movement of the arm before hearing the noise of the hammer? — 2. How fast does sound travel through the air? — 3. Is it through air only that these vibrations can be transmitted to us?

1. You hear it even better than if the vibrations reached you through the air, *for vibrations are transmitted with greater rapidity and strength by solids and liquids than by air.* Sound travels through wood 10 times more rapidly than through air, through iron 15 times, and through water 4 times.

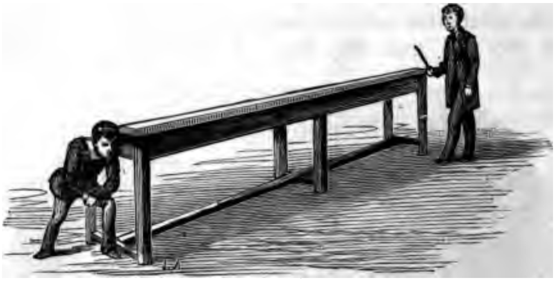

Fig. 51. — *Solids* transmit sonorous vibrations better than *air.*

142. Reflection of sound. — **2.** *Sound is reflected back from a solid or liquid body, just as light is.* It is for that reason that under some peculiar conditions, a sound once emitted may be heard several times. This is called an *echo.* **3.** Echoes are generally to be heard when one is in front of a high wall or a large rock. If you then cry aloud, you first hear your own voice; the sound goes forward, strikes against the obstacle, and is thence reflected back and reaches your ear, so that you hear it again. This is a *simple* echo; but there are often *double* and *triple* ones, etc. In the castle of Simonetta near Milan*, there is an echo that is said to repeat 32 times.

143. Ranges of sound. — Sounds differ greatly from one another. There are *deep grave* sounds, and *high sharp* sounds; this difference is due to the number of vibrations per second to which these sounds correspond. **4.** *The more numerous the vibrations are, the higher the sound is.*

---

1. Compare the rapidity of sounds transmitted to us through air, with those that come through solids and *liquids.* — 2. Mention a property of *sound* analogous to one of light. — 3. When does an echo generally take place? — 4. What results from the number of these vibrations being more or less numerous?

The deepest, the gravest tone that it is possible for us to hear, has 32 vibrations per second; the highest, the shrillest has about 70000. Man's voice can scarcely go below a sound that gives 164 vibrations per second, nor woman's voice higher than 2088 vibrations; but you children go much higher than that in the shrill cries you sometimes utter.

144. Musical intervals. — You may have already begun to study music. If so you know your notes, and something of the *scale**, the *octave**, the *fifth**. **1.** It will then no doubt interest you to know that *when a note is an octave above another, the higher note has just twice as many vibrations, as the lower one;* when a note is at the fifth it has 3/2 more.

2. We shall see this better with the help of our tuning fork, the mid *la* of our voice, this **la** is produced by 806 vibrations per second. The *do* under it has 480 vibrations; the *do* above this, $480 \times 2 = 960$ The *sol* (the interval from *do* to *sol* is a fifth) gives $480 \times \frac{3}{2} =$ 720 vibrations.

145. Musical Instruments. — I must however mention, that instruments by which we obtain musical sounds are of several kinds.

3. First there are **stringed instruments**, in which sound is produced either by *rubbing* on the tight strings with a bow*, like those of the fiddle or the violoncello, or by *striking* them with little hammers like those of the piano (fig. 52), or again by pulling them sharply with the fingers, like those of the harp, or guitar.

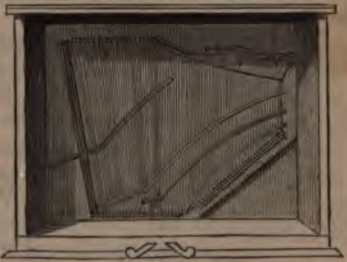

Fig. 52. — Interior of piano. — The longer the string the deeper the sound; the shorter the string the shriller the sound.

4. *The longer the string, the deeper the sound; the*

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1. What may be observed when a note is an octave higher than another? — **2.** By how many vibrations in a second is the mid *la* produced? — **3.** In what category of instruments is the fiddle ranked? the piano? the guitar? — **4.** What is the law of the vibrations of chords?

SUMMARY. — SOUND.

1. **Vibrations** (p. 177). — **Sound** is always produced by the shock of one body upon another.

2. This shock produces *vibrations*, which are transmitted to the air and thence to our ear.

3. **Velocity of sound** (p. 178). — In air, sound travels at the rate of 1125 feet per second.

4. Sonorous vibrations can be transmitted to us by solids and liquids better even than by air.

5. **Echo** (p. 180). — Sound can be **reflected** back from a solid or a liquid body, just as light is reflected from a mirror.

6. This reflection of sound is what is called an **echo.**

7. **Low tones and high tones** (p. 180). — There exist *low* or *grave* tones, and *high* and *sharp* ones.

8. The greater the number of vibrations, the higher and more acute is the sound.

9. A sound is an **octave** higher than another when it gives *twice* the number of vibrations than this other sound gives.

10. **Musical instruments** (p. 181). — There are *stringed* instruments and *wind* instruments.

11. In stringed instruments the *longer* the string is, the *lower* is the sound it emits; the *shorter* the string, the higher is the sound.

12. Likewise in wind instruments, the longer the pipe, the deeper and graver is the sound.

13. Sounds are strengthened by elastic plates of wood (as in the case of the piano, the violin, etc.).

14. **Diapason tuning fork** (p. 182). — The tuning fork is generally constructed so as to give the *la* (806 vibrations per second).

[At page 232 subjects of composition are given.]

V — ELECTRICITY.

147. Sound, light and heat have been known to man ever since his appearance on the globe. But it is scarcely two hundred years since he had any knowledge of electricity, although lightning had many a time made him witness of its effects.

148. Friction develops electricity on the surface of wax and glass. — Here is a stick of **sealing wax** (fig. 58). I present the end of it to *little bits of* paper, no effect is produced.

1. But if I rub it sharply upon my sleeve (fig. 59), *the little bits of paper are instantly attracted, even from the distance of about a quarter of an inch* (fig. 60).

If in this experiment a **glass rod** is used, instead of the stick of wax, *the same result is obtained.*

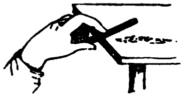

Fig. 58. — I place the stick of sealing wax near the paper : no result!

Fig. 59. — I rub the sealing wax...

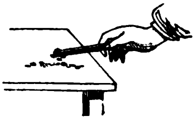

Fig. 60. — It attracts the paper.

2. *Friction has then developed on the surface of the* **wax,** *and of the* **glass,** *a certain force,* capable of lifting little bits of paper : this force is **electricity.** Ah! we are still far from the terrible lightning; but wait a little, we shall get to it.

149. The two states of Electricity. — I will now show you something more curious still. With a thread of silk I suspend to a sort of little stand, a small ball of elder pith (fig. 61). **3.** I let my *stick of sealing wax* touch this ball of pith, it having been previously vigorously rubbed. *You see the pith ball is energetically attracted,* just as the bits of paper were, only *no sooner has the pith ball come in contact with the stick of wax than it is repelled to the point* A. You

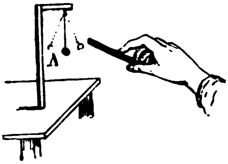

Fig. 61. — The litte ball of elder pith is repelled, as soon as it touches the wax A.

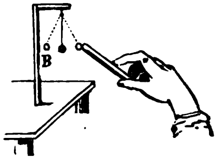

Fig. 62. — The elder tree ball that fled from the wax is attracted by the glass rod, but as soon as the contact has taken place it is again repelled to B.

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1. What happens when little bits of paper are placed near a stick of sealing wax that has been previously rubbed? — 2. What name has been given to the force developed on the surface of the wax and the glass? — 3. What happens when a ball of elder tree pith is placed near a stick of sealing wax, that has been rubbed?

see I can drive it away in any direction, if I pursue it with the wax.

1. I then immediately take up my **rubbed glass rod** (fig. 62), and put it in the place of the wax. *The pith ball that was repelled by the wax is attracted towards the glass rod; but in a short time it is again repelled*, and can only be attracted again by the **wax**.

2. This experiment would lead to the belief that there exist two kinds of electricity, *one given by glass and the other given by wax.*

3. For this cause the name of **vitreous electricity** has been given to the former, and **resinous electricity** to the latter.

4. They are also called, for reasons too difficult for you to understand as yet, **negative** electricity for the resinous, and **positive** electricity for the vitreous.

All bodies thus emit electricity when rubbed, sometimes *negative*, sometimes *positive;* but its existence is not always so manifest as when glass or wax is acted upon.

150. Attraction and repulsion. — Here now is a thick plate of *resin* upon a wooden support (fig. 63). I rub it for a good while with a bit of woollen stuff. It then not only attracts light bodies, but also, every time my finger (fig. 64) approaches it, *it gives off little sparks, that spring from it with a*

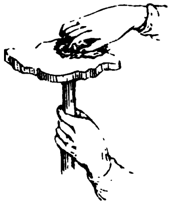

Fig. 63. — I rub the resin with a piece of woollen cloth.

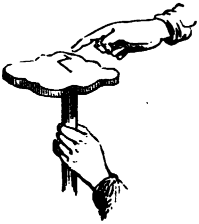

Fig. 64. — I place my finger near it, and I obtain little sparks, and a slight crackling noise.

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1. What happens when a rod of glass is placed near a small ball, that was repelled by the wax? — 2. What seems to result from this *experiment?* — 3. What name is given to the electricity of wax? To the electricity of glass? — 4. What other names are used instead of *resinous* and *vitreous?*

slight crackling noise. This is real lightning in miniature, the spark is the *lightning*, the little noise the *thunder*.

Suppose, that, instead of the little ball of pith I hung on the stand, I had in its place put a ball of *resin* carefully rubbed. **1**. If the **resin** was placed near the ball, *the latter instead of being attracted would be repelled.*

2. If on the contrary, *I held near it the large* **glass rod**, the *ball of resin would be attracted by it.*

3. Now if on the stand a *glass* bead were hung, it would be attracted by the resin, and would fly from the glass rod.

4. From these experiments, delicate enough to be repeated, the two following laws have been deduced.

1. *Two bodies charged with similar kinds of electricity repel each other.*

2. *Two bodies charged with different kinds of electricity attract each other.*

151. Conductors and non-conductors or Insulators.

See, with this stick of sulphur, after friction, I can also lift up bits of paper. In dry weather you may even draw electricity from your own hair, by the friction of the comb. Cats also, I may say, especially, emit electricity, and their fur stands on end when stroked, even gently (fig. 65), when the weather is dry or frosty; if this be done in the dark, quantities of little sparks can be seen to spring out from under one's hand with a slight rustling noise.

Fig. 65. — When cats are rubbed in dry weather they give out electric sparks.

But things do not work in like manner if I take my **iron** rod. **5**. I *may rub as long as I like, I can produce no manifestation of the presence of electricity.* **6**. If, before

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1. What happens when a large piece of resin already rubbed, is placed near a small piece that has also been rubbed? — 2. What would happen if instead of the large piece of resin I place a small piece near a stick of rubbed sealing wax? — 3. What would happen if the little piece of resin were replaced by a bit of glass? — 4. What laws may be deduced from these experiments? — 5. I rub an iron rod and keep it in my hand: by doing so, shall I be able to attract the little bits of paper to rise? — 6. And if I wrap some folds of silk round the part of the ruler that I hold, what then?

beginning to rub it, however, I wrap several times around it a piece of **silk** (fig. 66) I can see the rod give some signs of electricity, that is to say, I can lift with it some small bits of paper.

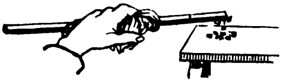

Fig. 66. — If I wrap a piece of silk round the iron, it attracts the little pieces of paper.

What does this indicate?

1. This indicates that before I wrapped the silk round the iron *the electricity as soon as it was produced passed through the iron into my body and thence into the ground;* whilst at present, the rod being wrapped in silk, the electricity remains on the iron. But why was silk necessary to obtain this result? That is what I will now explain to you by an experiment.

I will operate this time with a stick of wax that has not yet been used, and which you see cannot as yet attract anything. Very carefully and gently I rub the extremity on my sleeve, the extremity alone (fig. 67).

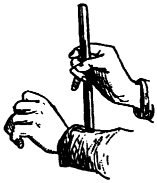

Fig. 67. — I rub the *extremity* of a stick of sealing wax on my sleeve.

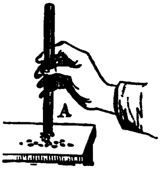

Fig. 68. — The extremity alone of my stick of sealing wax attracts the bits of paper. There is no effect at A. The wax is a *non-conductor.*

You see (fig. 68) it attracts bits of paper and other light bodies; yet at a very short distance from the end A no effect whatever is obtained.

2. *Thus electricity occurred only where friction had developed it,* and had by no means spread over the wax. **3.** For this reason wax is said to be a **non-conductor** of electricity. We have already made acquaintance with this term when speaking about heat.

4. On the contrary when I produced electricity by

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1. What does that imply? — 2. In what way does electricity affect the wax? — 3. By what word *do we express* this quality in the wax? — 4. How does electricity affect an iron rod? — By what word do we express this property in iron?

rubbing my iron rod, *the electricity immediately spread itself over all the surface*, for iron is a **conductor** of electricity. **1**. Now the human body is also a conductor, although less so than iron; so is also the ground. Therefore no sooner was electricity produced in the rubbed part of the iron rod than it *passed into my hand, thence to my body, and finally into the ground*.

2. As for the silk, it is a non-conductor. *So in wrapping the silk round the iron, I kept in, as it were, the electricity* on the iron, and by dint of patient rubbing, produced enough to allow all the rod to give manifest signs of its existence.

3. *To keep in the electricity produced, is called* **insulating** *a body*. People use for this purpose : silk, glass, resin, wax, porcelain, India rubber, all of which are non-conductors. Woollen stuffs, dry leather, dry wood, are not good conductors either. On the contrary, **metals**, water, and wet bodies, such as live plants, animals and wet ground are good conductors of electricity.

152. Different methods of obtaining electricity. — **4**. 1st electricity can be produced by *friction*; 2nd by bringing an unelectrified body into actual contact with an electrified one; 3rd by bringing an electrified body near to an unelectrified one (without allowing them to touch).

Thus we can get electricity. 1st by *friction*, and under proper conditions; 2nd by *contact;* and 3rd by *induction.*

1st When a body is rubbed it becomes charged with a certain quantity of electricity, which varies according to the nature of the body, *positive* in the case of glass, *negative* in that of resin.

2nd When a body is touched by another body previously electrified, the former becomes charged with electricity of *similar nature*. In the experiment with the pith ball hung by a silk thread, the ball attracted by the wax became charged with negative electricity (that of the resin);

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1. Explain now, why the bar of rubbed iron does not attract the pieces of paper? — 2. Explain why the bar of iron wrapped up in folds of silk attracts them? — 3. How do we express the action of opposing the electricity produced? — 4. What are the different modes of electrifying a body?

but as soon as there was contact, it was immediately repelled, because two electricities of similar nature repel one another.

3rd Electrifying action. Suppose you have a ball (fig. 69), charged with positive electricity. If you put this ball near another body, B standing on an insulating foot, the body B divides itself as it were in two halves: that next to the ball C becomes charged with negative electricity; the other D with positive electricity. Hence this body if moveable will be attracted towards the electrified body, as electricities of different natures are mutually attracted.

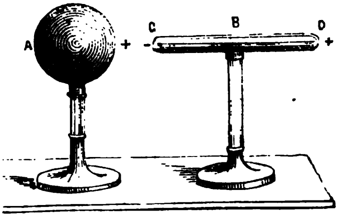

Fig. 69. — Electrifying action. — The vicinity of the ball A, charged with positive electricity, brings into C a negative electricity, and at D positive electricity.

153. Power of points. — When a body capable of being a good conductor is electrified, if perfectly round (fig. 70), *the electricity is equally spread over all its surface.* If it be egg-shaped (fig. 71) the electricity *will collect especially at the two ends.* If we suppose the egg-shaped body capable of being lengthened out as this bit of paste can be, *all the electricity* will *collect at the two points.* Were I to taper to a point one of the ends (fig. 72), leaving the other round, *all the electricty would go to the point;* the body would be unable to *retain* any, all would run out as it were at the point.

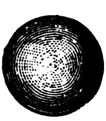

Fig. 70. — Electricity is spread all over the surface in a ball.

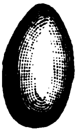

Fig. 71. — In an egg-shaped body electricity will collect especially at the two ends.

Fig. 72. — In a body terminated in a point all the electricity escapes by that point.

This is what is called the **power of points.** **1.** It consists you see in this, *that a body charged with electricity discharges itself rapidly if it is tapered off*, or merely if a pointed body be stuck in it or applied to it. Of course the body must be a conductor of electricity, else the electricity would quietly remain where it was developed, without being able to reach the point.

It is *this power of points that allows* **lightning conductors** *to be of any use; and it is also this power that causes the lightning to be attracted especially to steeples and tall trees such as poplars.* We must examine further into this.

154. A Lightning conductor. — We have already seen that when two bodies are charged, one with negative electricity, the other with positive, they are mutually attracted. When they come in contact with each other, or even when they come pretty close to each other, a **spark** passes between them, and their electricity *disappears :* they are said to be *discharged* (*neutralised* would be a better expression). More than this, if the electrified bodies were tapered to **points** the discharge *would take place with so much ease that it would not even produce sparks.*

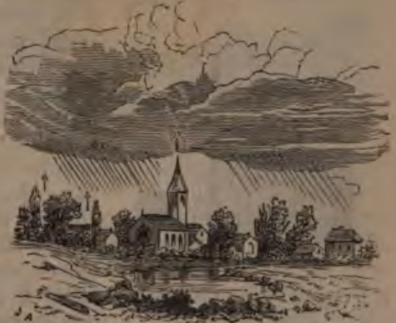

Fig. 73. — Electricity glides gently toward the points, steeples or tall trees, and from them into the air, and into a cloud.

2. Thus when a cloud charged with negative electricity approaches the earth (fig. 73), *it electrifies by induction the earth, whose positive electricity* as I explained to you a little time ago, accumulates upon all pointed objects. **1.** Then if the cloud is not too near, or if it is not too strongly charged, or again if

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1. In what consists the power of points? — 2. What happens when a cloud charged with negative electricity approaches the earth? — 3. How does electricity affect the cloud if is not too heavily charged?

a shower has caused all those pointed objects to become better conductors than usual, being wet, the electricity will *glide gently away* from the points in the first place, thence into the air and the cloud, which will thus be neutralised.

1. But if the cloud contains a great quantity of electricity, or if the electricity of the earth has at its disposal but an insufficient number of pointed bodies to be able to pass away with sufficient rapidity, *all of a sudden, a spark, in this case a* **flash of lightning,** *springs forth, sometimes proceeding from the point to the cloud, sometimes from the cloud to the point,* as the case may be. **2.** This flash is what is vulgarly called the **thunder bolt,** which strikes, in preference as you know, trees and spires, especially when they have but few tall objects around them.

— But, Sir... — Well, what do you wish to ask, George? — But then, if you put a lightning conductor on the steeple (fig. 74) as has been done here, there will be no escape possible, and the lightning cannot fail to fall on that long sharp rod? Quite right, my child. But do not be afraid. Have you ever looked closely at this lightning conductor of the church steeple? Is there nothing besides the iron rod? — Oh! yes, *there is a long iron chain, that runs down all along the building.* — And where does this chain finish off? I have heard say that it passes down into a well, but I do not know if that is true, or why it should be so. — It is quite true, and I will tell you why it is so.

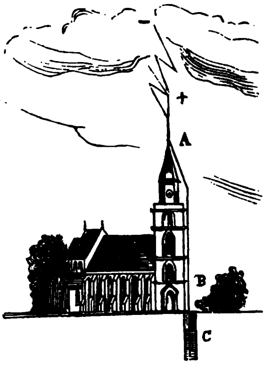

Fig. 74. — If a thunder bolt falls, it follows in preference the chain AB and is lost in the earth C.

When the cloud passes over the church, the water of the well, the iron chain and the rod of the lightning

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1. What happens if the cloud contains a great deal of electricity? — 2. What name is given to this spark?

conductor will always be in better condition to conduct electricity than any other part of the edifice, although it may be wet with the rain. **1**. The result of this will be that the electricity of the earth will always choose the easiest path towards the cloud. **2**. And if a flash does spring forth, it will, in *falling* as people say, more readily take the road that offers least resistance. Electricity is lazy or at any rate prefers avoiding difficulties to overcoming them. This is the reason why the lightning conductor will either discharge the electricity of the cloud slowly and without flashes of lightning, or if there be a flash of lightning, the consequences will be borne by the conductor itself, that is to say, the rod, the chain, and the well, so that the church will be preserved.

155. Two kinds of lightning. — Please, Sir, *does lightning fall somewhere on the earth, at every discharge of electricity from the clouds?* — No, my child. **3**. There are flashes that take place *between the earth and the thunder cloud, and it is in such cases that things on the earth are struck.* **4**. Fortunately, however, in most cases lightning flashes *from one cloud to another;* one cloud being charged with positive the other with negative electricity (fig. 75); these clouds discharge themselves in coming near each other. **5**. Lightning is accompanied by a great noise called *thunder*, produced by the displacement of air. **6**. This noise is prolonged by *echoes* rolling from cloud to cloud. The flashes that pass from the

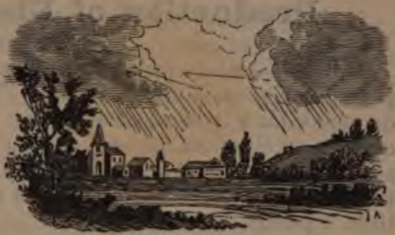

Fig. 75. — The discharge most frequently takes place between two clouds.

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1. What happens if a cloud charged with electricity passes over a church that has a lightning conductor? — **2**. What takes place when a lightning flash approaches the earth? — **3**. Name one sort of lightning. — What are the consequences of this kind of lightning? — **4**. What is the second sort of lightning? — **5**. By what are these sparks accompanied? — **6**. Why does this noise produce prolonged rollings?

earth to the *cloud*, produce on the contrary a sharp short thunder clap.

A certain interval of time, of greater or less duration, exists between the moment the lightning is seen and that at which the thunder is heard. Could any of you explain to me why? — **1**. Sir, the lightning is seen as soon as it is produced, *because light travels very rapidly*. — Very well; and sound? — **2**. Sound *only travels* 1125 *feet in a second* and is much longer on the way. — Quite so, my child, and the knowledge of this fact gives great facility for measuring the distance at which the lightning has been produced. **3**. *Count the seconds, between the time you see the lightning and the time you hear the thunder, as many times* 1125 *feet as there are seconds, form the distance which separates you from the place of disturbance.*

Production of Electricity.

156. — And now let us return to the means employed for producing electricity. You can easily understand that it is impossible to obtain considerable quantities of electricity by merely rubbing a stick of sealing wax, with a bit of stuff in one's hand. The quantity thus developed is of no other use than to afford a little scientific amusement.

4. Electricity is produced on a large scale, by two kinds of instruments, namely, *electric machines and electric batteries* or *piles*.

157. **Electric machines**. — **5**. Electric machines (fig. 76) *generally produce electricity by friction upon glass*. They are most frequently composed of a plate of glass A revolving between two pairs of cushions CC′ DD′, that press on either side of the glass and rub on it as it turns. The electricity, which is positive in this case, accumulates upon the metallic parts of the machine, so that when a large machine of this description is

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1. Why do we see lightning as soon as it is produced? — **2**. Why does an interval of time pass between the lightning and thunder? — **3**. How can we measure the distance that separates us from the point at which lightning is produced? — **4**. By the help of what instruments is electricity produced? — **5**. How do electric machines produce electricity?

employed, sparks strong enough to knock down a man, may be obtained; these sparks are sometimes about half a yard long.

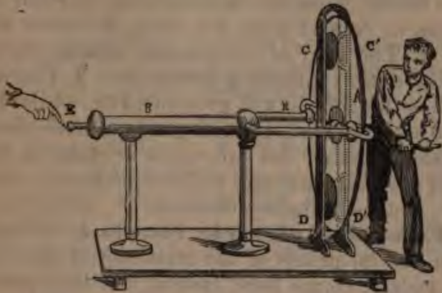

Fig. 76. — The rubbing of the glass wheel A between the cushions CC', DD', produces positive electricity, which accumulates at B.

158. Electric batteries and piles are of a totally different nature, and work upon quite another principle. 1. You must be aware that *whenever a chemical decomposition, or to use a more appropriate expression, a chemical re-action takes place*, **electricity is developed**. Thus when, in the course of our first lesson on chemistry, we made sulphate of iron, with some sulphuric acid and some iron, a certain quantity of electricity was produced; only as we paid no heed to it, it was lost.

In electric piles things are disposed so as to gather it in or condense it. Peculiar dispositions are adopted according to the chemical reaction chosen.

In order to give you a pretty accurate idea of these piles I will make a very simple one before you. This very simple pile (fig. 77), I am going to construct for your instruction, is similar to the earliest pile ever made, that invented by the celebrated Volta*. See, I pile up *pennies*, *discs of zinc*, *and discs of cloth*, all of similar dimensions, arranging them as follows, a penny, that is to say copper, cloth, and

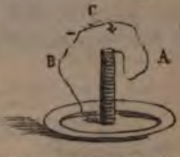

Fig. 77. — Electric pile. The wire A touching the copper gives positive electricity. — B, wire touching zinc gives negative electricity. — C, the union of these two poles, producing the electric current.

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1. Upon what principles do electric batteries work?

zinc. When about ten of each have thus been piled up, I tie up the whole, dip it in some strong vinegar for a few moments, then wipe it and lay it on a plate. This done, two brass* wires are fastened, one beneath and one above; one in contact with the *zinc*, the other with the *copper*. **1**. The acid of the vinegar attacks the zinc; a *chemical re-action is thereby produced.* **2**. The wire, A, that touches the copper will give positive, whilst that, B, in contact with the zinc, B, will give negative electricity. **3**. If I fasten together the two wires or poles as they are called, an **electric current** will be produced, very weak of course, but nevertheless obvious.

159. Effects of electric current. — I will now show you several proofs of the existence of this current.

FIRST PROOF. Come here, Henry, and hold out the tip of your tongue (fig. 78). There, I have placed the end of the wires on it; do you feel anything? — Yes, Sir, a saltish taste.—Anything else! **4**. Ah! a sort of shaking in my tongue. — That's *caused by the passage of the current.* If instead of this poor little pile, I employed a strong one, you would be unable to bear it on your tongue. Between your fingers even it would feel painful, and would give you violent shocks.

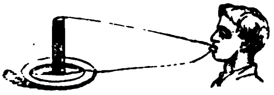
Fig. 78. — Henry feels a slight trembling on his tongue : physiological effect.

SECOND PROOF. Here is a **mariner's compass** (fig. 79) composed as you all know of a needle set on a pivot,

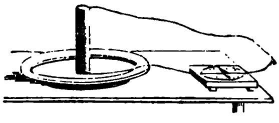
Fig. 79. — The needle of the mariner's compass puts itself parallel with the wires of the pile. Physical effect.

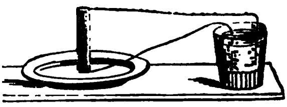
Fig. 80. — The water is decomposed into gas (oxygen and hydrogen) by the electric current. Chemical effect.

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1. What is there in the battery we have just constructed that causes the electricity to escape? — 2. What sort of electricity comes from the wire A that touches the copper? What sort of electricity comes from the wire B that touches the zinc? — 3. What will happen if I unite these two wires? — 4. Name a physiological effect produced on the tongue by the electric current.

ch needle *points to the* **north**. I lay the united 's of the pile upon the compass. **1**. Immediately *the lle deviates and places itself parallel with* the 's of the pile.

UIRD PROOF. This time it is a glass of salt water 80), that will manifest to us the existence of the ent. The two ends of the wires are immersed in the r at some distance from one another. Be all eyes pay great attention. **2**. Do you see, that after a few nents, little bubbles form at the end of each wire, disengage themselves and rise to the surface? *se bubbles are the result of the decomposition of water, produced by the action of the electric cur-*, as we shall see hereafter.

DURTH PROOF. Lastly, let us carry our pile into the closet (fig. 81), shut every thing carefully so as to in complete darkness. ite and separate several s the two poles of the **3**. You can see at each act *a small, very small, k appear.*

Fig. 81. — A little spark appears, at each reunion and separation of the two wires.

nd so we have obtained our rough apparatus all effects that strong elec- machines give : 1. Ac- upon the human body, *physiological effect*; tion upon the magnetic le, and the production parks giving light and heat, or *physical effect*; e decomposition of water, or *chemical effect*.

it with large batteries or piles very extraordinary ts are obtained. **4**. A single shock is capable of wing the strongest man into convulsions, or even of ng him. **5**. When the sparks are made to pass be- n two points of carbon they produce the marvellous

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lention a physical effect pro- by the electric current on the of the mariner's compass. — me a chemical effect produced ter by the electric current. — me a second physical effect produced by the union and separation of the two piles of the battery. — 4. What effect is produced by a strong pile upon a man? — 5. Tell me of two applications of electricity to industry.

and splendid *electric light,* which is now used to light up our great cities.

1. By the aid of electricity, divers bodies can be decomposed and metals deposited upon other bodies, as in gilding or silvering. And how many other marvels might I mention, but the list would be too long. **2.** Amongst the most useful applications is the *electric telegraph* that carries news all round the world, by means of a wire, along which electricity runs with a fleetness equal to that of light; the *telephone,* that bears to a distance and reproduces the human voice, so that at the Exposition of Electricity, which took place for the first time in Paris in 1881, people were able to hear all that the actors and singers said or sung in the great Opera, although at least two miles distant; the *microphone* also, that amplifies sound so as to render audible what was imperceptible, to such an extent that a fly walking over a sheet of paper, makes as much noise as a horse prancing on a sonorous floor. Ah! it would take a life-time to study the half of all these marvels.

SUMMARY. — ELECTRICITY.

1. Positive electricity. — Negative electricity (p. 185). — *Friction* develops on the surface of wax and of glass a certain force called **electricity.**

2. Electricity obtained from wax is called **negative** electricity.

3. Electricity obtained from glass is called **positive** electricity.

4. Bodies charged with *positive* electricity **repel** those charged with *positive* electricity.

5. Likewise, bodies charged with *negative* electricity **repel** those charged with *negative* electricity.

6. On the contrary bodies charged with *positive* electricity **attract** bodies charged with *negative* electricity.

7. Hence the two following laws:

1. *Bodies charged with similar kinds of electricity repel each other.*

2. *Bodies charged with electricity of opposite kinds attract each other.*

8. Bodies that are good conductors, bodies that are bad conductors (p. 187). — If instead of rubbing *wax* or *glass*

Tell me of two applications of electricity to industry. — **2. Tell me of the** *g raph.* — *Of* the telephone.

I were to rub an **iron** rod, the electricity formed by the friction spreads itself over the rod, passes through my body and disappears in the soil.

9. In the case of the wax and the glass it is the contrary: the electricity *remains* just where the friction developed it.

10. It is said, for this reason, that iron, the human body, the earth and water are **good conductors** of electricity.

11. Wax, glass, and silk are **bad conductors.**

12. In order to obtain any manifestation of the presence of electricity in the rod, I am obliged to wrap around it several folds of silk.

13. This process of thus keeping in electricity, by means of a body non-conductor, is called **insulation.**

14. **Electric sparks** (p. 186). — When one holds their finger near a large plate of resin that has undergone vigorous and prolonged friction, small *sparks* issue forth with a dry crackling noise. This is in reality a miniature thunder storm, the spark is the lightning and the crackling noise the thunder.

15. Bodies can be electrified by *friction,* by *contact* or by *induction* (p. 189).

16. **Power of points** (p. 190). — Electricity concentrates itself at the end of any pointed object, so that a pointed body which is a good conductor *discharges its* electricity at the point.

17. *Lightning conductors* (p. 189). — This *power of points,* which induces lightning so frequently to fall upon spires and tall trees, etc., is applied to the construction of lightning conductors.

18. A lightning conductor is composed of a long pointed rod, to which is attached a thick iron chain that descends into a well.

19. When a stormy cloud, we will suppose charged with *negative* electricity, comes near enough to the earth, it attracts all the *positive* electricity.

20. This being the case, one or the other of the two following phenomena must take place.

1. If the cloud is not too near, or if it is not too heavily charged with electricity, the electricity contained in the soil will glide gently away towards the point of the lightning conductor, and thence into the cloud, which will thereby **be neutralised.**

2. If on the contrary the cloud be heavily charged with electricity, the spark will spring between the conductor and the cloud, and the electricity will be guided along the iron chain and disappear in the well.

21. Fortunately the greater number of flashes of lightning *pass from one cloud to another,* instead of passing between the earth and a cloud.

22. **Electric machines and electric batteries** (p. 194). — Electricity can be artificially produced by two kinds of instruments, *electric machines* and *electric batteries* or piles.

23. The machines produce electricity by friction.

24. Electric batteries are made on the principle that *whenever a*

chemical composition or **decomposition** *takes place, in other words*, whenever a **chemical reaction** *is obtained*, be it *strong* or *weak*, **electricity** *is produced.*

25. Batteries give both negative and positive electricity.

26. On bringing together the two wires which unite both electricities, an *electric current* is obtained.

27. From this current there can be obtained *physiological* effects (a trembling in the tongue, convulsions, sometimes even death), *physical* effects (deviation of the magnetic needle, sparks, electric light), *chemical* effects (decomposition of water).

[Simple *Subjects for composition* are to be found at page 232.]

VI — MAGNETS.

160. — Look at this horse-shoe shaped piece of steel (fig. 82). To outward appearance it has nothing extraordinary about it. But see, if I present its two ends to a sewing needle (fig. 83), when within half an inch of it, the needle *raises itself from the table, flies towards the instrument I present to it, and clings fast upon it*; a sharp shake is necessary to make it quit its hold.

Fig. 82. — A magnet.

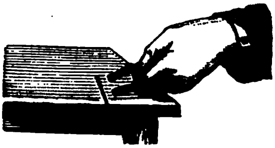

Fig. 83. — The needle flies to the magnet, and clings to it.

This piece of steel *that attracts both iron and steel*, is what is called a **magnet.**

161. Attraction of iron by the magnet. — Here mingled together and spread out upon a plate are some iron and copper filings, sawdust, cinders, coal dust, and sand (fig. 84). At some distance above the plate I pass the two ends of my magnet. 1. *See how the iron filings are attracted by it and firmly adhere to it;* whilst the copper and all the rest remain quite still. **The magnet attracts iron only.**

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1. What is the effect of the magnet on iron filings? — What is the effect of the magnet on copper, and certain other bodies?

1. The action of a *magnetic bar* is almost exclusively *limited to its two ends.* You may observe that with the curved part of my magnet I can scarcely make

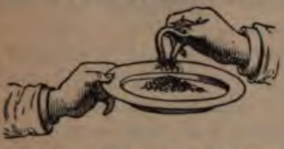

Fig. 84. — The magnet only attracts iron.

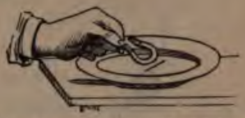

Fig. 85. — The curved part hardly acts at all.

the needle move (fig. 85). 2. And this is the reason why magnets are generally made in the shape of a horse shoe, so as to be able to act with both ends at a time.

162. Distant action of the magnet. — *Magnets*, as you see, *can act at a distance*, for the needle moved while the magnet was half an inch distant; and nothing can prevent this action. In proof of this I place the needle on a sheet of paper, on a bit of silk, or on a pane of glass (fig. 86). 3. You can pass the magnet under the object thus separating it from the needle; *notwithstanding the obstacle, the needle faithfully follows the magnet in whatever direction it takes, the intervening body being incapable of preventing magnetic action.*

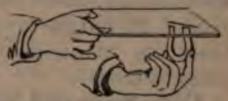

Fig. 86. — The needle follows the magnet even at the other side of the sheet of glass.

163. Magnetism by contact. — Let us now put the needle upon the two ends of the magnet, and bring it near the iron filings (fig. 87). 4. The filings are immediately attracted towards the needle and adhere to it, thus you see, *the needle has been magnetised by its contact with the magnet.* We may now separate the needle from the magnet, it will nevertheless retain its power of attracting the iron filings (fig. 88). *The needle has itself become a magnet.*

Even until lately this was the process by which all

---

1. Do all the parts of a magnetic bar act in the same manner? — 2. Why are magnets generally made in the form of a horse-shoe? — 3. Does the needle follow the magnet even when separated by glass? — 4. Can the needle in its turn become a magnet? How?

magnets used in physics were made. A piece of steel was rubbed upon a previously prepared magnet; this sufficed to magnetise the former immediately. I say steel, not iron, for although this latter is very *easily magnetised*, more easily even than steel, yet ***it does not retain its magnetic power;*** when iron is quite pure, it loses its magnetism as soon as its contact with the magnet ceases.

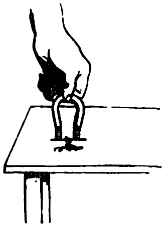

Fig. 87. — The needle is magnetised. Magnetism by contact.

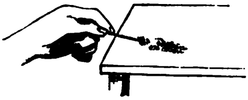

Fig. 88. — The two ends of the needle attract the filings.

164. Natural magnet. — What makes you look so perplexed, George, when I say that magnets are made by rubbing a piece of steel with a previously magnetised magnet. — Sir, I was wondering where the first magnet came from; it at least could not have been made by rubbing it against another, since no other existed. — Ah! well, that bit of curiosity will soon be satisfied; in fact, it was about this that I was just going to speak to you.

All magnets are not artificial, there exist also *natural* magnets. A certain iron ore called loadstone*, has the power of attracting iron. This ore is abundantly found in Sweden, and also in Asia Minor*, near an ancient Greek town *Magnesia.* Hence the name of *magnetism* was given by the Greeks to the peculiar properties of this ore. This word is used, with the same signification up to the present day. You understand now, master George, do you not? **1.** ***With natural magnets, steel bars have been rubbed, from them artificial* magnets obtained, and so on.*** In our

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1. *How* were the first magnets obtained?

days, people have other modes of arriving at the same result. I will tell you of these in an ensuing lesson.

And now let us pass on to something else.

165. Magnetic attraction and repulsion. — Here is a steel knitting needle. I magnetise it by rubbing it with a magnet : it attracts as you see the iron filings at both its ends. I suspend it by the middle to the stand (fig. 89) we used in a preceding experiment. The knitting needle moves about, *oscillates* as we ought to say, and finally remains motionless in a certain direction.

Then, to one end A, of the suspended needle, I present one of the ends A′ of my magnet; the needle is most evidently attracted. And in that fact there is nothing to astonish us. But wait a little, wonderful things are to happen, only as they are somewhat complicated in appearance, we will take the precaution of marking A, A′, at the ends of the magnet and of the needle which attract each other.

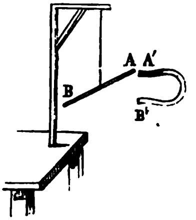

Fig. 89. — The extremities of the two magnets are attracted or repelled.

During this time the needle has become quiet again, and has returned to its primitive position. I present to the end A of the needle the end B′ of the magnet. Strange to say, the needle is repelled from the magnet. We will draw back our magnet, and wait till the needle gets settled again.

Let us see what will happen now if we put to the end B of the needle (the one we have not marked), the end B′ of the magnet : the attraction is manifest. Let us present the end A′ : the needle is repelled.

So when we bring near each other two magnets, *their ends attract or repel each other* (fig. 89).

Now in order to see clearly through all this, we will magnetise two knitting needles AA′ (fig. 90) placed alongside one another. 1. For this purpose I set the marked end of my magnet on the middle M of the two needles, and gently rub them with the magnet from the middle to one of the ends AA′, repeating this opera-

---

1. What is to be done in order to magnetise a needle by rubbing?

tion several times. Then I take the other, the unmarked end of the magnet (fig. 91), and rub from the middle to the end BB′, the part of the needle that remained untouched the first time, and as in the preceding case, repeat the rubbing several times.

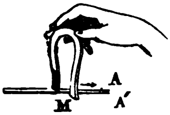

Fig. 90. — I several times rub the two needles from M to AA′.

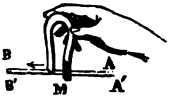

Fig. 91. — In the same way I rub the two needles from M to BB′.

The two needles are now magnetised. To avoid confusion we will put ink on the ends BB′ of the needles (fig. 92), then we will suspend one of them by its middle, the one marked AB for instance. We shall subsequently see that if we present to the end A of the suspended needle the end A′ of the other needle, the end A is repelled; if it is the end B that is presented, on the contrary A is attracted. The reverse is the case if the end B is applied.

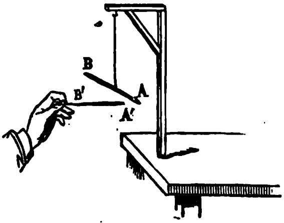

Fig. 92. — A′ repulses the extremity A, but B′ attracts it.

Fig. 93. — The duck is attracted or repulsed according as one or other end of the magnetised needle is presented to it.

1. *Thus there are at the two ends of one needle, or, to use the proper expression, at the two* **poles**, *two kinds of magnetisms, as there are two sorts of electricity at the two ends of a body electrified by induction, or at the two poles of an electric machine.* It is perfectly evident that there is the same magnetism at B and B′ on one hand, and at A and A′ on the other.

---

1. In what do the two ends of a magnetised needle differ?

1. We can thus say that *poles of similar nature repel each other whilst, poles of opposite nature attract each other ;* the rule is the same as that applicable to electricity.

Henry was aware of the fact although unable to explain it, as his uncle brought him from town a small metal duck that floats on water and follows or flees (fig. 93) from a magnetic needle according to the end presented to it; and this because in the duck's bill a piece of magnetised steel is hidden. I asked Henry to bring me his toy, here it is, and you see how very docile the good duck is.

166. Mariner's compass. — And now let us return to our suspended knitting needle. You see, of its own accord it has set itself in a certain direction; if I turn it aside, it *oscillates* a while and **returns** to its first position. Now note in what direction it turns. **2**. *One end points to the north, the other of course to the south.*

Fig. 94. — One end of the needle of the mariner's compass always points to the north.

3. The Mariner' compass (fig. 94) of which you all have heard *is merely a magnetised needle*, only instead of being hung on a thread, in which case the instrument could not be easily carried about without damage, it is placed on a pivot, which allows it to turn freely in any direction. It is moreover shut up in a box with a glass lid, so that nothing can harm it.

It is quite superfluous to insist upon the utility of the mariner's compass, and the immense service it renders to sailors on the trackless sea; for, as everybody knows, its needle, constantly pointing to the **north**, allows the cardinal points to be found under any circumstance whatever.

It is however necessary that there be no other magnet nor any mass of iron in the immediate neighbourhood of the compass, otherwise the needle would deviate * and give false indications. On board ironclad vessels, the regulation of the magnetic needle is therefore no easy matter.

The compass has been used in Europe for 4 or 5

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1. What are the laws of magnetic attraction and repulsion? — 2. What direction does a magnetic needle take when suspended? — 3. What is the mariner's compass?

centuries*, but it was known to the Chinese long before that.

167. Magnetisation by the electric pile. — I have already told you that magnets are no longer exclusively made by being rubbed with another magnet. The other process I then alluded to is the following: **1**. And in order to make the explanation as attractive as possible I will make a magnet before you. For this purpose I take a nail AB (fig. 95) of wrought iron; around it I wrap some straw, which is an insulating body, then taking one of the wires C of the electric pile we made a little while ago, I wind it a great many times round the straw. You can convince yourselves, that as far as at present, the two ends of the nail, which protrude through the windings of straw and wire, have no attractive effect on the iron filings. **2**. The things thus prepared, *I bring together at* E *the two wires* CD *of the pile, otherwise called the two poles; the electric current passes, and circulates* **around** *the nail; immediately the latter is magnetised and exercises attraction upon the iron filings.* When I interrupt the current, the iron filings fall off; when I again allow the current to pass, the filings cling once more to the nail, and so on.

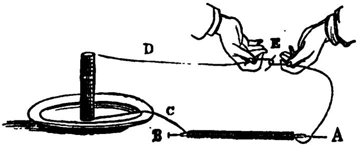

Fig. 95. — As soon as the electric current is passed through the wire, the nail BA is magnetised (electro-magnet).

3. Thus we have made what is called an **electro-magnet**, a word easily understood. Ours is of course but a very weak one, for it can scarcely lift tiny iron filings. But with strong currents electro-magnets have been made capable of lifting and holding suspended several tons weight.

Electro-magnets constitute the fundamental part of the *electric telegraph*, one of the many marvellous applications of electricity.

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1. What should be done in order to magnetise a nail by the pile? — 2. *Your arrangements being completed, what is now* necessary to be done in order to magnetize the nail?— 3. What name is given to iron thus magnetised?

SUMMARY. — MAGNETS.

1. **Magnets and magnetism** (p. 200). — A **magnet** is a piece of steel which has the power of attracting iron.

2. This power has been called **magnetism**.

3. If a steel needle be rubbed by a magnet it manifests magnetic power.

4. There are *two sorts of magnetism,* just as there are *two sorts of electricity.*

5. In a magnetised needle, if one of its extremities or *poles* take one sort of magnetism, the other extremity will take the magnetism of the opposite order.

6. Poles of similar nature **repel** one another; those of contrary natures **attract** each other. (The rule is the same as that applicable to electricity).

7. **The mariner's compass** is merely a magnetised needle placed upon a pivot. One end of the needle is constantly directed towards the **north.**

8. At the present day iron or steel is magnetised by the action of electric currents. This is the principle of the *electric telegraph.*

[Simple *Subjects of composition* are to be found at page 232.]

VII — WEIGHT OR GRAVITATION.

Weight and Density.

168. Force of gravity. — I hold in my hand a small stone and a sheet of paper. I let both go at the same time, and see, the stone has fallen straight to the ground, whilst the paper floats and oscillates an instant, but finally reaches the floor. What I have done with these two bodies I might have done with any others : *let go in the air, they would inevitably have fallen to the ground.*

I will take the paper and the stone in my hand once more, only this time before I let go the paper I will crush it up into a ball, as small and as tight as possible. There look; this time the paper ball falls as rapidly as the stone, and both reach the floor at the same moment.

1. *This is one demonstration of the fact that all bodies fall with equal rapidity;* when differences exist *they are solely caused by the resistance of the air, which is greater or less according to the extent of surface presented to it, the greater surface of course offering the greater resistance.*

Stand forward, James, and hold out your open hand (fig. 96). Here is a small ball of lead. I will let it fall into your hand from the height of about 3 inches. That does not hurt you, does it? — No, Sir. — Well, this time I will hold it a yard high before letting it fall. — Ah! this time I felt it more smartly. — Well, let us try once more. This time I will get upon the chair and let it drop from twice the former height. — Ah! this time it makes my fingers tingle. — Then that is enough. Now what should we conclude from this experiment.

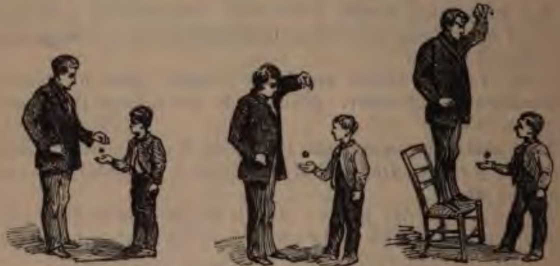

Fig. 96. — James: « That does not hurt me. »

« This time I felt it pretty smartly. »

« Ah! sir, this time you have made my fingers tingle. »

2. We must most evidently conclude that *the longer the fall lasts, the greater force it acquires, or in other words, the greater the distance through which a falling body has to pass, the greater is the rapidity attained.*

And this rapidity, when the body falls from a great height, is so considerable that one cannot see it pass. For instance, during the first second a falling body travels 12 feet 9 inches; the same body, in 2 seconds, passes through 43 feet; during the fifth about 138 feet; and

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1. As all bodies fall with the same rapidity, how is it, that a sheet of *paper falls* less quickly than a stone? — 2. What conclusion may we form from the falling of bodies?

about 231 feet during the 10th second of its fall. And so on, always augmenting its velocity more and more. Thus, were you to jump out of the school-room window, which is 3½ feet above the level of the court-yard, you would do yourself no harm; whilst were you to fall from the church steeple, which is 50 feet high, your bones would be broken on reaching the ground.

169. The Vertical. — A body that falls to the ground follows no capricious irregular course. **1.** If it has not been thrown, *it will always fall in a straight line* AB (fig. 97) *which is perpendicular* to the surface of the water.* **2.** This line is called **vertical**. **3.** In order to easily ascertain the vertical line, a somewhat heavy body is suspended to the end of a string; the weight of the body causes the string to hang vertically. **4.** This string with its heavy body is what is called a *plumb line* (fig. 98).

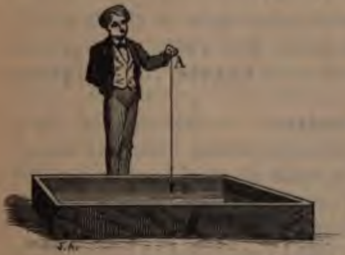

Fig. 97. — Vertical line AB is perpendicular to the surface of the water.

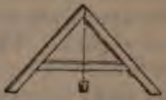

Fig. 98. — String with lead adapted for masons.

170. Weight of bodies. — This time, James, pray hold out both your hands, do not be afraid; I will not hurt you. I merely wish to put in one, A (fig. 99) a piece of cork, and in the other B, a piece of lead of equal dimensions. What difference do you find between these two bodies? — Oh! Sir, the lead is much *heavier* than the cork. — Very well, but tell me what you mean when you say it is "*heavier*"? — **5.** Well, Sir, I think it is *that I have greater difficulty in keeping it from falling.*

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1. What direction does a falling body take? — 2. What is its line of descent called? — 3. How may a vertical line be easily ascertained? — 4. What name is given to an instrument constructed to show this? — 5. What is really meant when we say that one body is heavier than another?

Exactly so. *All bodies fall with equal rapidity, but not with equal force.* You could hardly bear the fall of the lead ball, I dropped from the height of 2 yards a little while ago, whilst you might catch this cork in your hand without harm were it thrown from the top of the house, *a body that falls with greater force than another is said to be* **heavier,** *or* **weightier** *than another.*

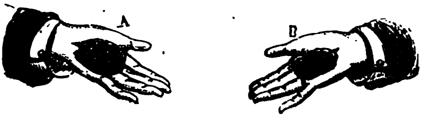

Fig. 99. — Sir, the piece of lead is much heavier than tne cork.

171. Density of bodies. — All this is not so simple as it looks. Once more stretch out both hands. This time I put in them a little piece of lead and a little piece of cork. The lead is still the heavier, is it not? — Yes Sir! — Very well, but now I heap on your hand a great many pieces of cork, until your hand is full. Which is the heavier now, the lead or the cork? — Ah! now it is the cork, but that is not astonishing, for it is ten times bigger than the lead. — Astonishing or not, that matters little. It is nevertheless true that the cork is now weightier that the lead. What can you say to that? — **1**. Ah! Sir, *to be able to compare the weight of the lead with the weight of the cork, it is necessary that both be of* **the same size.** **2.** Quite right. We will then conclude that a body is "heavier", or "**weightier**" than another, or in other words that it has a greater **weight** than another, when it falls with greater force than the other, *whatever be its volume*: thus we say, a large cork is " weightier " than a little ball of lead; but when of **equal dimensions** one body is heavier than another, we may conclude that the heavier is "**denser**", the lead then, is " denser " than the cork.

But it is not only solid bodies that have greater or

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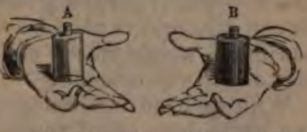
1. What conditions ought two bodies to present if we wish to compare *them?* — **2.** When is it said that one body is heavier or weightier than another? When is it said that one body is denser than another?

less weight, greater or less **density**, here is a small bottle **1.** A full of water (fig. 100) and another B, of equal size full of mercury. Weigh them in your hands as you did with the lead and the cork. What a difference there is betwen them! And no wonder for a *certain volume of mercury is 13 ½ times heavier than an equal volume of water*; or to use another expression, *the density of mercury is 13 ½ times greater than that of water*. For convenience sake, people have agreed upon taking water as the standard in this matter, *the density of water then being one, that of mercury is* 13 ½ or 13.6.



A, water. B, mercury.

Fig. 100. — The density of water A (weight of the same volume) being 1 that of mercury B is 13.6.

2. In like manner it is said that the density of lead is 11.4; that of gold 19.3; that of iron 7.8; that of ordinary stone, 2.7; that of glass, 2.5; that of oak wood, 0.6; that of wine 0.9; that of pure* alcohol, 0.8.

Lastly *gases also have weight*, and different degrees of density. **3.** Air is 773 times less heavy than water; yet it weighs something, for a bottle full of air is heavier than one from which, by means of an air pump, the air has been totally removed.

172. Balances. — You were easily able to tell me a little while ago, that the piece of lead was heavier than a piece of cork of the same size, and this simply by weighing them in your hands; but that was because the difference was very considerable. You would not be able to detect slight differences. In such cases you must have recourse to instruments called **Balances** or **scales**. There are several kinds of balances. The simplest and most in use (fig. 101) are composed of a vertical* stationary rod AB and a horizontal* movable* rod DC, placed so that its middle be exactly at the top of the vertical rod.

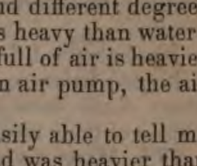


Fig. 101.—Ordinary scales. CD, beam.

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1. Explain what is understood by the word *density*, taking for example water and mercury. — 2. Name the density of any other bodies. — 3. Has air any weight? — What is the weight of air compared with that of water?

At each end of this horizontal rod called the *beam* of the balance, two pans are hung. *When these pans and their suspending chains are exactly of equal weight, the beam remains perfectly horizontal**. So it remains if an equal weight is placed in each pan. But if there be additional weight in one pan, the pan containing the heavier object will descend.

With such an instrument one not only learms if the two bodies have equal weight, but the difference between them can also be ascertained. For this purpose the body whose weight you wish to know, is compared with others of which the weight is previously known, and which are used as standards or units. The principal unit or standard in the metric system is the *gramme*, the weight of a cubic centimetre of distilled * water.

173. How to measure the weight of solid bodies. — See, I put in one of the scales the body I desire to weigh, let it be this piece of lead, for instance. In the other I add weights until the beam become altogether horizontal. .I have then only to add up these weights to ascertain exactly what the piece of lead weighs.

The balance I described was the common rather old fashioned balance, with the pans hung under the beam. Many other sorts exist, but we must leave aside the details of their mechanism.

174. How to measure the density of solids. —Now if with the help of my scales and my piece of lead I wish to calculate this time, not the *weight* but the *density* of lead, I could also very easily do so.

I already know the weight of this piece of lead (we shall call it P). If I knew the weight of a volume of water equal to that of the lead I would but have to divide P by p and the proportion $\frac{P}{p}$ would give the density of the lead.

In the first place however the volume must be ascertained and that looks rather difficult on account of the irregular shape of the piece of lead. This difficulty will be easily overcome, by taking a vessel the capacity of which has been measured, and on which different measures are indicated by figures: this vessel is what *is called a graduated gauge*. I pour in water until it rises to the number 100. Then I drop into the vessel the stone; the water rises to 160. What is the volume of the stone, Master Paul? — Evidently as the stone takes up 60 divisions.

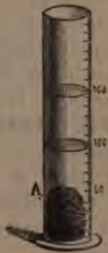

Fig. 102. — The level of the water which was at 100, mounts to 160, the difference indicates the volume of the lead A.

Now I know the weight of the water that fills up those 60 divisions of the gauge; I have thus the weight p; I measured P directly. The density then is $\frac{P}{p}$, that is to say in short 11.4. So the lead weighs proportionately. 11.4 times heavier than water.

You see that the density of lead is inferior to that of mercury. Strange enough it is to see a piece of lead float on the surface of mercury as a cork would do upon water.

175. How to measure the density and the weight of fluids. — **1**. When we wish to weigh a solid, nothing is more simple: we put it directly in one of the scales, whilst in the other we add weights until we balance both.

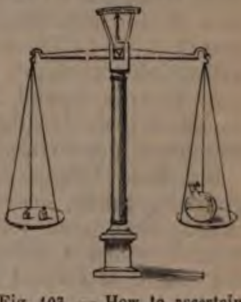

Fig. 103. — How to ascertain the weight of a liquid or of a gas.

2. In order to know the weight of a liquid, we put it into a vessel and weigh both together; afterwards we ascertain what is the weight of the empty glass, and deduct its weight from that we found for the whole.

3. Thus it is we ascertain that mercury weighs 13.6 times heavier than a equal volume of water; consequently its density is 13.6. In like manner we find that the density of sulphuric ether is 0.7, that of water being always taken as standard.

The weight and density of gases are ascertained in like manner.

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1. What is the density of lead? Of mercury? — 2. How do you ascertain the weight of a liquid? — 3. Of a gas?

In the case of air, for instance, a bottle full of air is weighed in the first place; then with an air pump which will shortly come under our notice the air is extracted. The bottle of course then weighs less. The difference is evidently the weight of the air extracted. The volume of the bottle being known the density of the air is thus deducted. It is 773 times lighter than water.

176. Relation between temperature and density. — When it is said that the density of gold is 19.3, that of mercury 13.6, that of air 773 times less than that of water, it is necessary to specify that those measures have been taken at the temperature of 0° centigrade.

Do you see the reason for this, Paul? Do you know if a cubic inch of gold at 0° will weigh more or less than a cubic inch at 100° centigrade?—It will always have the same weight, for it will always be a cubic inch. You are mistaken there, my child. Listen to this.

Here is the cubic inch of gold. At the freezing point, it weighs so much. If I put it in boiling water, it will expand, as I have already told you. So it is no longer a cubic inch, but a cubic inch and something over. If I pare off this something over, it is quite evident that the weight will be lessened. So at 100° the cubic inch will weigh less than a cubic inch at zero.

As **liquids** expand much more than *solids*, the differences in their density at different degrees of temperature are still more important.

But these differences are nothing compared to those given by **gases**, on account of their excessive elasticity*. One given volume centimetres of air at 0°, *increases about a third part of its bulk* at 100°. So the weight of a equal volume of air at 100° diminishes a third part.

You can see by all this that it is quite indispensable when speaking of the density of gases and liquids to mention at what temperature they were measured. And to simplify things as much as possible, the temperature of melting ice is always taken as a standard. The only exception made is in the case of water, whose density is taken at 4° above zero. Thus, when it is said that a cubic centimeter of water weighs so much, you must *know that* it is at 4 degrees. For, strange to say, it is at the temperature of 4° that water attains it greatest density.

Now I hope you all know with sufficient accuracy what is meant by the *weight* and the *density* of a body, and that you are also capable of finding both out.

Pressure of Liquids.

177. Outflow of liquids. — Let us go now into the garden, and see what we can learn from the humble water-butt. See I have turned the tap at the bottom and the water gushes forth, shooting out to a good distance. If you put your hand in the jet, you will find that the water comes out with no little force.

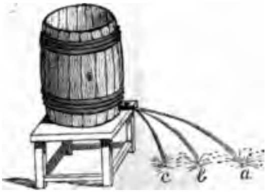

Fig. 104. — As the cask becomes empty, the jet becomes less and less strong, and goes back from *a* to *c*.

1. As the cask becomes empty the *jet diminishes in strength,* from *a* (fig. 104) it goes back to *b*, then to *c*, and *finally the water would fall almost straight down.* But you know all that, so we will turn off the tap, as we shall require more water in a little time.

Were I to ask you, Henry, what makes the water shoot out so, what reason could you give? Sir, it is the weight of the water in the cask, since the more water there is the stronger the jet is. *It is the water that pushes.*

178. The pressure depends upon its height. — Quite right, it is the water that pushes. But it is not, as you might believe, the whole bulk of the water, *the quantity that there is in the cask has nothing to do with the matter : it is its* **height** *that is important.*

Now let us return to the schoolroom; I will there demonstrate to you, with a very simple instrument, what I have just asserted.

This instrument, which I made with my own hands to avoid expense, is composed of a tin tube AB (fig. 105)

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1. I turn on a tap placed at the bottom of a butt full of water; what happens to the jet when the cask is nearly empty?

well corked at the lower end. I have pierced in it a little hole, at C, corked also for the time being. At A I have adjusted a second tube D much narrower than the first, and the whole is filled with water to a certain height. The instrument contains, as I have previously ascertained, 60 cubic inches of water, 10 of which are in the tube D. I now withdraw the little cork, and the water springs out to a good distance, and reaches G, but it rapidly loses strength and falls near the tube: let us measure the distance, G. It is 8 inches.

I cork the little hole again, and instead of the little tube on the top, I put a large funnel D (fig. 106), and pour in water to the *same height* as before. For this I have required 300 cubic inches of water, 100 of which are in the funnel: so you see *it contains* 10 *times more* than the little tube. George, when the cork is taken out, will the water spring to a greater distance than it did last time? — Yes, Sir, as there is in the funnel ten times more water than there was in the tube, it will push ten times harder. — Well, you are wrong there. But pull out the cork and judge for yourself. Do you see, *the water shoots no farther than* 8 inches. Ah! the jet lasts much longer because there is a greater quantity of water: **1.** ***but it has no***

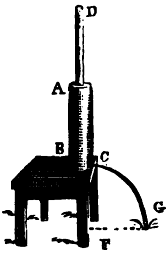

Fig. 105.

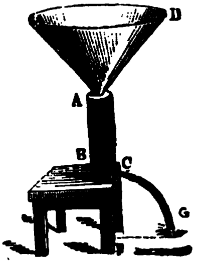

Fig. 106.

Whether there be a simple tube AD, or a large funnel, the water flows to G, 8 inches from F, for it is not the quantity of water that influences the force of the jet, *it is its height that is everything.*

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1. I procure a simple tin tube, and a funnel. What will become of the jet of water, that I allow to flow from the bottom of the tin tube?

greater force than in the first case. You see, then, I was right in saying that **height** *alone was important.*

Here is another proof.

I have here a tube similar to the first, except that it is five times its length (fig. 107); it contains but half the quantity of liquid that was in the funnel. This I fix on my tin tube, and begin to pour water into it. But, bang, out flies the cork C before the upper tube is half filled D, and the jet shoots at a distance of at least 15 inches. What can be the reason of this? It is, that the pressure of the water was so strong that the cork was unable to support it, and yet there was less water than in the funnel a little time ago.

179. Measure of the pressure. — 1. *This leads to the conclusion that the pressure of water on the bottom of a vessel depends only on the* **height** *of the water.* So, if you pour water into a vessel (the bottom of which has a surface of one square inch) until it reaches the height of one inch the pressure it exerts is equal to the weight of a cubic inch of water. If the water poured therein reaches the height of ten inches the pressure exerted will be equal to the weight of 10 cubic inches of water, and that *whether the vessel be* **tube** *shaped or like a* **funnel.**

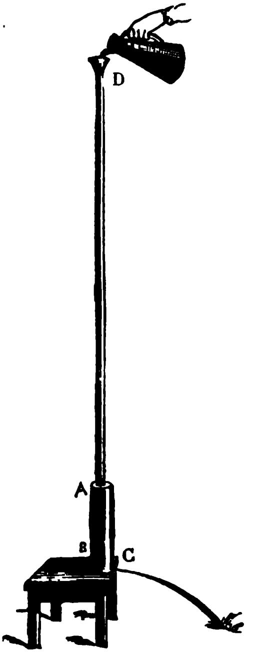

Fig. 107. — The pressure has made the little cork fly out. Although there is less water in the tube than in the funnel, because the *height* CD is much greater.

Very evidently if the bottom of the vessel presented a

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1. Why has the jet of water coming from the funnel no more force than that coming from the tube?

surface measuring 2 square inches, the pressure would be equal to the weight of 2 cubic inches of water at an inch high, of 20 cubic inches of water at the height of 10 inches. For naturally, each square inch of the surface of the bottom supports on its own account an equal weight.

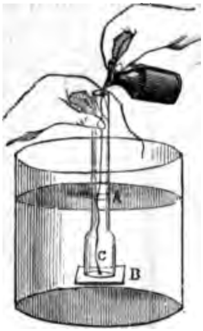

Fig. 108. — The cardboard B, sustained by the pressure the water exercises upon it from below, only falls when the water poured into the lamp-glass is on the same level as that in the vessel.

A very simple experiment will show clearly the pressure of liquids, and will give us at the same time its measure.

I take the glass of a common lamp (fig. 108), and put below it a bit of cardboard B, that fits closely against it, I then plunge the whole in a vessel full of water. The pasteboard, which I kept close to the lamp-glass at first by a thread, remains in its place without any other help than the upward pressure exerted upon it by the water in the vessel. I then pour water into the lamp-glass. As soon as the water reaches the same level as the water in the vessel, the cardboard is displaced and falls to the bottom. This perfectly indicates that the pressure exerted from *below* on the cardboard was equal to a column of water having for base the opening C of the lamp-glass, and for *height* that marked CA.

180. Influence of the density of liquids. — Of course the greater the density of a liquid, the greater will be the pressure of a column of this liquid. Therefore it is evident that since the density of mercury is 13 $\frac{1}{2}$ times greater than that of water, the pressure of a column of mercury 1 foot high will be equal to the pressure exerted by a column of water 13 $\frac{1}{2}$ feet high.

181. Equilibrium of pressure. — Tuck up your sleeve, Charles, and put your hand flat (fig. 109) at the bottom of this pail of water. Do you feel anything? — The water is very cold. — That may be, but that is not what I want to speak about. Do you feel the water weigh on your hand. — No, sir, not at all. — And yet do you *think it* ought to weigh? — Yes, of course, for my hand is at the bottom of the pail. — Here then is something new, the weight of the water is on your hand and you do not feel it.

But in the first place, measure how much the water should weigh on your hand. The height AB, of the water in the pail is 10 inches, and I suppose the surface of your hand takes up the space of 6 square inches. But in order to get on faster I will calculate in your stead. **1.** So there is weighing down upon your hand a column of water measuring $10 \times 6 = 60$ cubic inches the weight of which presses down upon your hand, and yet you are not conscious of it.

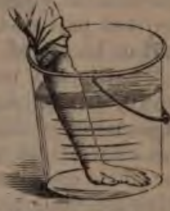
Fig. 109. — You do not feel the weight of 5 lbs because the water weighs equally on *all* the parts of your hand.

Suppose now that a fish whose body presents a surface of 6 square inches swims 100 inches deep. It has to support a pressure equivalent to the weight of 600 cubic inches, and so on. Fishes have been found in the sea at such depths that supposing the surface of their body to be 6 square inches, they had to support the weight of 20,000 pounds (fig. 110). Twenty thousand pounds weight upon the body of a poor fish, and yet it is not crushed, it even has no difficulty in swimming.

This is very strange is it not? And yet it is quite natural.

Fig. 110. — The fish is not crushed because the pressure is exercised equally on *all* parts of its incompressible body.

How could the fish be crushed? *The body is composed of solids and liquids, and we have seen that solids and liquids*

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1. You plunge your hand to the bottom of a pail of water, how would you calculate the pressure exercised on your hand?

are almost incompressible, thence almost incapable of being crushed.

— But, Sir ... — Well, what, Henry? say on. — Sir, you say that solid parts and liquid parts cannot be crushed; yet only yesterday I saw our neighbour the blacksmith crush his finger under his hammer. The bruised part was quite in a pulp. It was horrible, and had to be cut off.

That is sad indeed, poor man. But to continue our study, I must say that you are quite right to ask the explanation of things you observe, and I am happy to give the information you desire. These things are not easy for you to understand, and yet you must understand them. Give me your hand, and put it on the table just as the poor blacksmith had his on the anvil. There now; I will strike upon your finger with a hammer. Don't be afraid, I will only strike gently! Do you see how the hammer acts. It strikes only on the upper part of the finger, whilst the table is in contact with the under part. But on the *two sides* of the finger *nothing touches*, or *sustains* them. — The flesh thus pressed between the table and the hammer, were I to strike forcibly, would escape *sideways*, as a cherry stone would shoot out between your fingers, and would thus tear open the skin; the finger would then be crushed.

But if there were all *around the finger* a resistance equal to the force of the blow of the hammer, there would be no crushing neither sideways nor endways, nor above nor below the finger. And as this resistance would be wanting only on the part where the finger is joined to the body, in that direction only would the crushing or bruise be able to exert itself. If, in its turn, the whole body were *completely surrounded* by resistance equal to the force of the stroke of the hammer, crushing could take place in no direction whatever, and the body being incompressible there would be no bruise.

I make allusion, of course, to a body in which there is no gas, no air like that we have in our chest, which is very compressible indeed. We should be soon crushed to death, were we to be plunged 3000 feet under water, leaving drowning out of the question. Only what *I have* just said will allow you to understand how a *fish is not* crushed to death in the water notwithstanding the enormous pressure that sometimes bears upon its body. **1.** *For the pressure exerts itself, exactly in the same proportion all over its body, so that there is no reason why any particular part should give way and be crushed.*

Pressure of the Air.

182. Atmospheric pressure. — I have insisted on the case of the fish, because we are in a similar position, and like it pressed on all sides, bearing on our body a prodigious weight that no more crushes us than water crushes the fish. Only this time it is not water with which we have to deal, it is *air.*

2. Indeed, *air weighs on us just as water weighs on the fish.* And this weight, of which you take no heed, and under which you run and leap so lightly, may be estimated for you children at about 20,000 pounds.

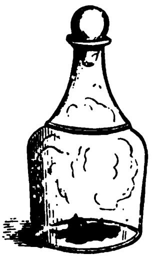

Fig. 111. — The air of the bottle dilated by the heat of the paper has made a vacuum in cooling. — It was then that the atmospheric pressure pushed the egg into the bottle.

Here is a very simple and amusing experiment that will give you an idea of the pressure of air. I take a wide-necked bottle, and a hard-boiled egg (fig. 111) the shell of which has been carefully taken off. You see the egg fits nicely into the neck of the bottle. But we will not leave it there. I see you think this a very funny and not very scientific-looking experiment. But listen and observe, and you will see the experiment has more importance than you might at first imagine.

I now introduce into the bottle a bit of burning paper. When the paper is almost consumed, I replace the egg on the neck of the bottle. Wait a little now; you see the egg is sucked gradually down, and then all at once enters the bottle with a loud report. What has pushed it in? *Simply the weight of the air.*

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1. Why is a fish not crushed in the water? — 2. What is the pressure that air exercises on us? How great would you suppose this pressure to be?

And how? You now know enough of physics to follow and understand my explanation.

The burning paper heated the air contained in the bottle. The air expanded by heat, found no longer sufficient room in the bottle, therefore a considerable quantity, perhaps one half was expelled and mingled with the surrounding atmosphere. At that moment I placed the egg on the neck of the bottle, completely stopping up the opening. When once the bottle was a little cooled, the air it contained *tended to return to its primitive volume*, which the heat had doubled. **1.** In that condition *it no longer opposed sufficient resistance to the outward pressure of the air*, so the egg, soft and easily lengthened out, being unsustained from below and pressed upon from above, gave way under the effort of the external air, and was thereby pushed into the bottle.

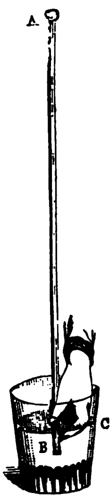

Fig. 112. — The tube closed at A, open at B, remains full of water, and does not empty itself in the glass. — It would be the same for a tube that was 11 yards high.

183. The measurement of the weight of air. — Another experiment may be made. Here is a glass tube about 3 feet long (fig. 112), it is solidly closed at one end by a cork well surrounded by sealing wax. *I fill this tube with water;* then with my finger I stop up the open end, and invert it into a glass filled with water. I withdraw my finger, *the tube nevertheless remains full. The water does not fall into the glass, but remains as suspended*, 3 *feet high in the tube.*

What can thus sustain it? **2.** *The pressure that the air exerts upon the surface C of the water in the glass*, and consequently upon B at the under surface of the column of water, but it cannot on account of the cork exert its force on the upper surface at A. The proof of this is, that if the cork be taken away the whole contents of the tube

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1. Why does an egg sink in a bottle in which a vacuum has been made? — *2. I place* in a glass of water a tube full of water, the water does not run out. What prevents it?

will run out and pass into the glass, as it is easy to show you.

If the tube were 2, 4, 6, 8, 10 yards long, the result would be the same. **1**. But were it longer, 12 yards for instance, *we should find that the water poured into it would not stand higher than about* **33.8 feet** *above the surface of that contained in the vessel into which the tube is plunged.*

2. This very evidently shows that *the pressure of the air, or to use the expression employed in physics, the* **barometric pressure** *is capable of holding in equilibrium a column of water* 33.8 *feet high.*

But it would be no easy matter to construct or to handle a glass tube of this dimension, and I do not think in schools, at all events, experiments will ever be made with such instruments. In fact there is no reason why this should be, for we have a better way of going to work.

184. Barometer. — We have as you will remember at our disposal, another liquid, *mercury*, whose density is above 13 times greater than that of water. It is then easy to conceive that a column of mercury 1 foot high, for instance, will be the same weight as a column of water of the same diameter and standing 13.6 feet high. Therefore, to have the equivalent weight of a column of water 33.8 feet high, a column of mercury of $\frac{33.8}{13.6}$. = 2 feet 6 inches would be required.

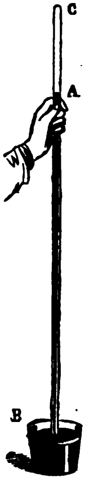

Fig. 113. — A column of mercury AB 2 f. 6 in high, stands still at the atmospheric pressure exercised at B.

A tube of this dimension is manageable, and we will forthwith set to work and see if our calculation gives us the result we expect. I will take the tube we were using a little time ago, and in order to be sure of the

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1. If my tube full of water had been twelve yards high, what would have happened? — 2. What does that imply?

stopping of the upper end I will close it (fig. 113) by melting the glass in a strong flame so as to fuse it up.

There, it is all right, and the tube cooled. I now proceed to fill up the tube with *mercury*, and, as I did a little while ago, will stop up the opening with my finger and immerse it in a glass B containing also some mercury : immediately, some of the mercury runs out of the tube, so the column sinks and stands still at a certain point. Hold the tube erect, Henry, while I measure at what height the mercury stands above the level of the mercury in the glass. **1.** *I find it to be* **2 feet 6 inches**, just what we found by calculation.

2. This tube full of mercury is what is called **a barometer**, from two Greek words, *baros* weight, *metron* measure.

185. Relation between the height of the barometer and the altitude* of places. — 3. If, instead of making the foregoing experiment here, in this low lying country, we had gone to fill our tube with mercury on the top of some mountain, *the column of mercury would not have stood so high.* At the top of Mount Blanc (5243 yards) it would have fallen to 16 inches and a half. In the Balloon ascent of the 15 April 1875, in which two Frenchmen, Sivel and Crocé Spinelli, lost their lives from asphyxia, at the height of 9370 yards, the mercury fell as low as 10 inches.

4. And this is quite easy to understand, since, evidently *the higher one rises, the less air remains overhead;* consequently *the less the air presses down, the less power it has to sustain a column of mercury.*

Thus you see that the height of the barometer is not the same in all parts of the world. Besides, it varies in a given place according to different circumstances, especially in unsettled weather.

186. Value of barometric pressure. — If we then consider that the mean pressure, at the level of

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1. I replace the water by mercury, how high a column of mercury can the atmospheric pressure sustain ? Why ? — 2. What name is given to an instrument thus constructed ? — 3. What would have happened if instead of filling the tube in a low lying country, it had been filled on tne summit of Mount Blanc ? — 4. Explain this diminution in the height of the barometer.

the sea, is able to support a height of 2 feet 6 inches of mercury, or 33.8 feet of water, we must conclude that each square inch of surface bears a barometric pressure equal to the weight of about 15 lbs. This is what is generally expressed by the words an **atmosphere** of pressure.

Let us apply the knowledge of this fact to the experiment we made with the bottle. The heat had expelled about the half of the air; therefore after cooling, the egg was **pressed** upon by all the weight of the air, by a whole atmosphere, and was *upheld* by only *half* an atmosphere, that is to say that the total pressure was half an atmosphere, or $7\frac{1}{2}$ lbs to every square inch of the surface of the opening of the bottle, evidently much more than was necessary to push the egg into the bottle.

It has been calculated that when the air is heaviest a man of average stature sustains a weight of about fifteen tons, which he does not even feel for reasons similar to those applied in the case of the fish in connection with the pressure of the water. And as the air is, by the mouth, in communication with the chest, we cannot be crushed. When one ascends to the top of Mont-Blanc, the pressure is about 8 lbs. per square inch. But that does not matter, since everything is in equilibrium, and the difference is quite unfelt. The disagreeable sensations and weakness that overcome travellers on high mountains arise from another cause. I shall have a word to say to you about this afterwards.

And now I hope you all understand *weight*, *density*, and *pressure*. You should also know how to measure them, what a *balance* or scales are, and also all about the *barometer*. These notions are all most important and if you have properly understood them, many difficult things will be but pastime for you.

187. Balloons. — As I already told you at the beginning of our lessons on weight, all bodies fall towards the ground, unless something keeps them up. I should not have been astonished had some of you interrupted me at that moment, nobody did so however. I must not allow those statements to pass without saying something about the little air balloons bought for children (fig. 114), and which have to be held by a string to keep them from flying away; you might also have mentioned the real large balloons (fig. 115) that rise in the air and are able to carry away in their cars

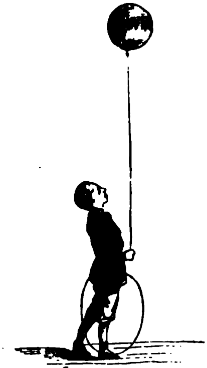

Fig. 114. — These little balloons are filled with a gas lighter than air (hydrogen).

Fig. 115. — Large balloons contain the same gas that is used for lighting the streets, houses, etc.

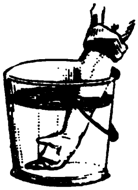

Fig. 116. — The cork let go in the water mounts to the surface.

several men. These are exceptions, are they not? Well no, they are not exceptions.

Do you remember anything else that rises when let go, instead of sinking? No, nothing at all. George, come here to me; take this cork, put your hand down with it to the very bottom (fig. 116) of this pail of water, and once there let it go. — Ah! Sir, it is not worth while, I know very well the cork will come to the surface. — O! you should have thought of that immediately. Yes, it will come to the surface, but for what reason?

Which is the less *dense*, the cork or the water? — The cork, since it rises! — Yes the cork is *less dense* than water. The cork then weighs less than *an equal volume of water*, that is to say, it would fall with less force. In consequence, if you let it go when under water, the water immediately above it will *fall* with greater *force* than the cork can, and so going below the cork will push it upwards. And this will go on, until finally the cork comes to the surface.

Let us make the experiment, but with a slight alteration. Before putting the cork under water I stick into it a pretty large nail, there now. You see the cork comes up, nail and all. But if I add another nail, and let the cork go mid-way between the bottom and the surface, it not only does not rise but sinks slowly down.

Well, it is just the same thing with the balloon. 1. *The balloon is a kind of bag containing gas, lighter, less dense, than air.* Sometimes it is heated air, sometimes the gas we burn. The balloon rises through the air just like the cork through the water; and as the latter was able to carry along with it a nail, the balloon can carry with it a car and men.

You see you can understand this very easily, it seems quite simple to you. Why? — Because you know what density is.

188. Application of the principle of atmospheric pressure. — I can show you another application of the principles we have learned to understand. On the surface of the water in my basin T (fig. 117) I put a piece of cork, and on the cork a piece of burning paper. Then, over the cork and the paper I invert an empty glass, which I push gently down into the water; big bubbles of air immediately escape from under the glass, and the paper ceases to burn. *Soon after, you see the water rise in the glass so as to almost fill it up to* AB. Paul, can you explain this? — Yes, Sir, I think so. The paper, burning under the glass, heated the enclosed air and caused it to expand, so that all of it could no

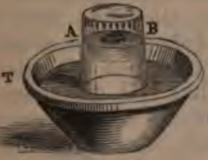

Fig. 117. — The burning paper has produced a vacuum in the glass. This space, the water occupies, being pushed by atmospheric pressure, and mounts as high as AB.

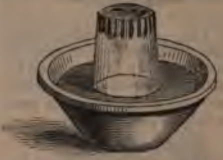

Fig. 118. — The water which fills the glass is maintained by atmospheric pressure, that acts on the water in the basin.

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1. Why can balloons rise in the air?

longer remain in the glass, some escaped in bubbles; then the air cooled down and contracted, allowing the water to rise in the glass and fill up the space left vacant. — Very well, but what forced up the water? — 1. The *atmospheric pressure* that weighed upon the surface of the water in the basin.

Now look here, I incline the glass in the water so as to fill it. I then lift it (fig. 118), and yet the water does not fall, how is this? — Sir, you have made a sort of barometer, and the water remains in the glass for the some reason as the mercury in the tube of the barometer. — Ah! very well answered.

189. Cupping glass. — Again I resort to my glass, which has already helped me to show you so many wonderful things. This time I light a piece of paper in it, then I apply the mouth of the glass to my arm (fig. 119) being sure that the edge fits nicely on the skin all round. The paper immediately ceases to burn, and in a few minutes my skin swells out and is sucked into the glass. It holds even very fast, and I should have great difficulty if I wished to pull it off at once, but if I disengage the least bit of the edge it comes off quite easily, and altogether as soon as the air gets in. You see clearly that this is just what happened with the water in the preceding experiment. 2. *The heated air has been expelled from the glass by expansion, and when what remained had cooled down, its contraction formed in the glass a partial "vacuum" which the skin weighed upon by atmospheric pressure tended partly to fill up.* 3. This last experiment was once much used for medical purposes, the glass in this case takes the name of *cupping glass.*

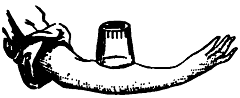

Fig. 119. — The burning paper has produced a vacuum in the glass. My skin pressed by atmospheric pressure is sucked into the glass, so as in part to fill up the vacuum.

190. Pumps. — See here is a little ear syringe, full of water. I hold it vertically dipping in the basin, and empty it by pushing down the rod. Then I slowly draw

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1. What causes water to rise in a glass in which a vacuum has been made? — 2. Why does the skin in part fill up a glass in which a vacuum has been made? — 3. What name do doctors give this operation?

up the rod again (fig.120), what is the result, James? — *The water rises in the syringe.* — Why? **1.** *Because the piston fits well, and the atmospheric pressure exerts itself on the surface of the water in the basin.* This also is on the same principle as the barometer. — Well. And how far could the water thus rise in the syringe? — To the top. And if the syringe were several yards long. — **2.** Still to the top, sir, *unless the syringe were longer than* 33.8 *feet in which case atmospheric pressure would not be strong enough.* — Quite right, my child. Now the whole theory of **pumps** is contained in what we have just seen. True, there are many kinds of pumps, and their action seems somewhat complicated; in reality however it is simpler than it looks, for all pumps are merely syringes more or less improved and perfected.

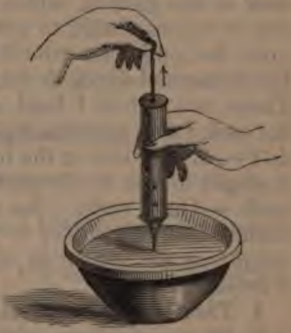

Fig. 120. — The water in the basin under the atmospheric pressure rises in the little ear syringe.

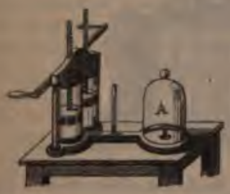

Fig. 121. — Pneumatic machines serve to exhaust from a vessel A, not water, but *air*.

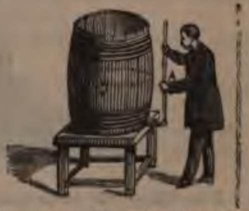

Fig. 122. — The water stops at A, at just the same level as in the cask.

3. Amongst these pumps, *one is very curious and is used to exhaust from a vessel* A (fig. 121), *not water but* **air.** This is what is called the *air pump*, or *pneumatic machine*, and with its help most curious experiments can be made.

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1. Why can we draw in water with a syringe? — **2.** What is the greatest length a syringe can have? — **3.** What is the use of pneumatic machines?

But before leaving physics, I have still something more to say to you.

191. Level of liquids. Let us return to our water-cask in the garden, which you remember we left half full of water. I affix to the tap with a bit of guttapercha tube, the long glass tube (fig. 122) with which we made a barometer and which this time I have opened at both ends. There now, while I hold my tube vertically alongside the cask I will open the tap. George, what will the water do? — It will rise in the tube. — How high? — I think it *ought to rise to the same height as that in the water cask.* — Quite right. See the tap is open, and the water rushes into the tube; it stops at A, exactly *the same height as the water in the cask*, or as people say, *on a level with it.*

1. *Thus water remains at the same level in all vessels communicating with each other.* This level is perfectly horizontal*, and the plumb line which is vertical*, falls quite perpendicularly upon it.

192. Fountains. — **2.** It is to reach the level of the reservoir R (fig. 123) placed on the little tower, that the water springs out of the fountain in the squire's garden. It cannot however quite reach the height of the reservoir, because the air offers a certain resistance;

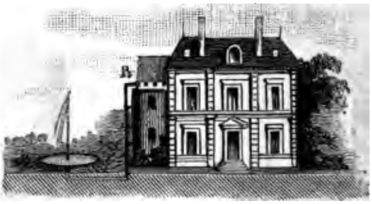

Fig. 123. — The water rises nearly to the height of the water in the reservoir B.

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* 1. A tube is put in communication with a cask full of water, the tube is held vertically, what will *take place?* — **2.** Mention an application of the power possessed by water, of finding the same level in conduits that communicate with each other.

but if a tube were placed upon the mouth of the fountain the water would rise exactly to the proper level, as it did in the tube fastened to the tap of our water cask.

SUMMARY. — Weight or Gravitation.

1. **Gravitation or falling of bodies** (p. 207). — All bodies fall with equal rapidity.

2. When apparent differences exist, they are owing to the resistance of air.

3. The greater the length of time a body falls, the more rapidly does it pass through space.

4. A falling body always follows a straight line called the **vertical**, which is perpendicular to the surface of water.

5. The *plumb-line* shows the **vertical** direction.

6. The **weight** of a body is the pressure it exerts when kept from falling.

7. **Density** (p. 210). — The **density** of a body is the weight of a given volume of this body as compared to that of a like volume of water.

8. The density of water then is said to be 1.

9. A given volume of mercury weighs 13.6 times heavier than an equal volume of water: its density is said to be 13.6.

10. A given volume of iron weighs 7.8 times heavier than an equal volume of water: its density is then 7.8.

11. A given volume of sulfuric ether weighs 0.7, taking water as the standard: its density is 0.7.

12. In order to ascertain the *weight* of bodies, balances or scales are used.

13. In order to ascertain the *density* of a body, the weight of the body must be divided by the weight of an equal volume of water.

14. The density of a body diminishes when its temperature is raised, because the body expands.

15. **Pressure of liquids** (p. 215). — The *pressure* a liquid exerts on the bottom of a vessel, depends only on the **density** of the liquid and its **height** in the vessel.

16. A tube containing a liquid may have an equal diameter from top to bottom, or it may be widened out like a funnel, the pressure on the bottom will remain unaltered.

17. A fish whose surface measures 6 square inches, swimming 100 inches deep, supports, calculating by the above-mentioned law, a pressure equivalent to the weight of 600 cubic inches of water.

18. The reason why the fish is not crushed is, that it is equally pressed upon in all directions at once, and that the solids and

liquids that compose its body are incompressible and consequently cannot be crushed.

19. **Pressure of air-barometer** (p. 221). — Air weighs upon us just as water upon the fish:

20. The pressure of the air can sustain a column of wate 33.8 feet high.

21. For greater facility, mercury is used instead of water, mercury being 13.6 times more dense that water. The height of a coumn of mercury kept in equilibrium by atmospheric pressure will thembe 18.6 times, less 2 feet 6 inches. *Barometers* are thus made.

22. Tne height of the column of mercury diminishes, if it be carried to the summit of some mountain or taken up in a balloon.

23. It is under the influence of atmospheric pressure that liquids rise in pumps, siphons, etc.

24. **Communicating vessels** (p. 230). — In vessels that communicate with one another, the water stands at the same level in all the vessels.

25. It is in virtue of this principle that the water of a reservoir in an elevated position, after having descended, rises again to its former level, be it in the form of a fountain or projected by a watering pipe.

SUBJECTS FOR COMPOSITION.

1st **composition** (p. 148). — The three states of bodies. — The three states of water, of zinc. — Are gases easily compressed? — Application to air. — Can liquids and solids be easily compressed?

2nd **composition** (p. 149). — Evaporation. — Ebullition. — Distillation.

3rd **composition** (p. 152). — Give an example of the expansion of solids under the influence of heat. — Liquids — gases. — Exception in the case of water.

4th **composition** (p. 155). — Construction of thermometers.

5th **composition** (p. 159). — Wood, charcoal, air, bad conductors of heat. — Why our clothing protects us against cold. — Why the handles of tools that are put into the fire are surrounded by wood.

6th **composition** (p. 161). — Force of the steam of boiling water. — Application of this force to machinery.

7th **composition** (p. 165). — Velocity of light. — Reflection upon mirrors. — Apparent breaking of bodies immersed in water.

8th **composition** (p. 168). — Concave lenses, convex lenses. — Focus of a lens. — Microscopes. — Spy glasses. — Spectacles for *near-sighted* people, spectacles for long-sighted persons .

9th composition (p. 173). — Dispersion of light. — Solar spectrum. — Why the paper of your copy-book looks white. — Why ink looks black. — Why a soldier's coat looks red.

10th composition (p. 177). — Vibration of bodies. — Air a propagator of sound. — Rapidity of sound travelling through air. — Do liquids and solids transmit sound? — Echo.

11th composition (p. 181). — Stringed instruments. — Wind instruments. — Deep, grave sounds. — Sharp, acute sounds. — The *la* of the tuning fork.

12th composition (p. 186). — Vitreous or positive electricity. — Resinous or negative electricity. — Attraction and repulsion. — What is meant by *insulating bodies*.

13th composition (p. 190). — Power of points. — Lightning conductor. — The two kinds of lightning.

14th composition (p. 195). — Electric batteries and piles. — Effects of electric currents.

15th composition (p. 200). — Attraction of iron by the magnet. — Magnetic attraction and repulsion. — Mariner's compass. — Natural magnets. — Artificial magnets.

16th composition (p. 209). — Weight of bodies. — Density. — How to ascertain both weight and density.

17th composition (p. 218). — On what depends the pressure of liquids on the bottom of the containing vessel. — Proofs.

18th composition (p. 221). — Atmospheric pressure. — Value of this pressure in water, in mercury.

19th composition (p. 227). — Application of the principle of atmospheric pressure: a glass full of water inverted in contact with a vessel of water and yet is not emptied; cupping-glasses, pumps.

20th composition (p. 230). — Water remains at a common level in a series of vessels which communicate. — Applications. — Waterworks, watering pipes, distribution of water through towns.

V — CHEMISTRY.

Fundamentals.

193. Differences between physical and chemical phenomena. — I hope you have understood and kept in mind, my dear children, what a *chemical* phenomenon is, compared with a *physical* phenomenon. **1.** In physics, one can always recover **in its primitive form** the body experimented upon. If heated, it cools; if electrified, it loses its electricity; if set in vibration, it subsequently comes to rest; if melted, it becomes solid again; if dissolved, it reappears when the liquid evaporates. **2.** This is far from being the case in **chemistry**: the bodies that have been experimented upon are totally changed, in fact they give rise to **other bodies** in which you could never directly recognise the primitive ones.

Fig. 1. — The sulphur that I burn *combines* with the oxygen of the air to form another body: chemical phenomenon.

See here is some *sulphur*; taken off those matches; it is a yellow, solid body, almost inodorous. I set it on fire (fig. 1), it burns and disappears; but in coming near it you feel an intense acrid smell that makes you cough. **3.** This odour is caused by the escape of a *gas*. The sulphur exists colourless in this odorous gas; you would never have fancied that, I am sure.

4. The sulphur in this gas is not alone; **it is combined**, as is said, with *another body*, which we shall

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1. What characterises a *physical* phenomenon? — 2. What characterises a *chemical* one? — 3. What *takes place* when you *burn* a piece of sulphur? — 4. Does the sulphur *alone* exist in this gas? — Was that a phenomenon?

shortly hear about. And the product of that *combination* is this gas.

This is the real distinction between chemistry and physics. In physics, one considers *one body only;* in chemistry, there are always *several* present.

Here is another bit of sulphur; let us put it on the blade of this old knife and heat it above the flame; we must take care to avoid its taking fire. **1**. You see it becomes liquid; yet it is always sulphur, and *sulphur alone*. The heat becomes greater; the little drop of sulphur grows less and less, and in a short time will have quite disappeared. The sulphur is volatilizing, it becomes a gas; but it is always sulphur, *sulphur only*. **2**. The proof is, that if I hold a cold plate above it while it is thus volatilizing (fig. 2), you would see deposited there very small yellow grains, those grains are *pure sulphur*, what is called *flour of sulphur :* the sulphur has been distilled as water would have been, that is all.

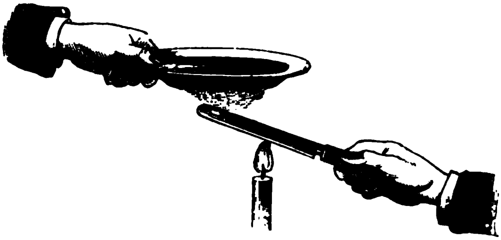

Fig. 2. — The sulphur, that we cause to *evaporate*, remains sulphur : a physical phenomenon.

It is altogether different when I *set fire* to it. The gas thus formed **is not pure sulphur**; it would not become solid on a cold plate.

You felt no smell when the sulphur volatilized, but this inflamed gas brings tears to your eyes and irritates your throat.

194. Compound bodies. — This gas is then not simply the vapour of sulphur. It is as I have already said, sulphur **combined** with another body. This other body was in the air, and had it not been

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1. In carefully *melting* sulphur what takes place? — 2. How do you prove that what is produced is sulphur only? Is it a phenomenon?

This seems to astonish you, Paul. — Why, yes, Sir, for we know *air* well enough, and it is a gas. Everybody knows it, and it is called one of the four elements; certainly it is a simple body. — And *water* also, in that case? Water also, yes, Sir. — And the *earth* also? — Oh no, we know that the earth is not a simple body : — Well, my child, let me tell you that the word element has led you astray, for neither air nor water are simple bodies. **1.** Air is *a mixture* of two simple bodies; water is a *combination* of two simple bodies.

196. Differences between a mixture and a combination. — Please, Sir, what difference is there between a *mixture* and a *combination?* — Oh, that can be most easily explained, but I prefer giving you an example.

See, here are some very fine iron filings, and there some flour of sulphur; I mix both together and shake and stir them carefully. **2.** You cannot at present distinguish the one from the other, so well are they mixed, yet they are but **mixed.** *The proof is that you can easily separate them.* **3.** You have only, for instance, to blow gently on them (fig. 5), the sulphur being by far the lighter will be blown away, whilst the iron will remain. **4.** Again, you might apply a more scientific method : take your magnet and pass it slowly quite near the mixture (fig. 6), all the filings will be at-

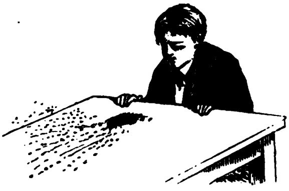

Fig. 5. — By gently blowing you can separate the flower of sulphur from the iron filings : *mixture.*

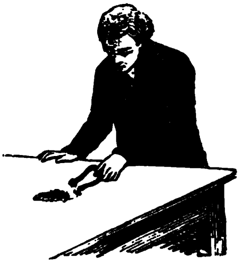

Fig. 6. — The magnet attracts all the filings, and leaves the sulphur : *mixture.*

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1. What is air? What is water? — **2.** Is there a mixture or combination when I mix iron filings with flour of sulphur? — **3.** Prove that there is only a mixture. — **4.** Give another proof.

tracted, leaving only the sulphur. The two bodies have merely been **mingled**, a phenomenon purely **physical**.

On the contrary, let us put our sulphur and our filings in this broken vessel, adding a little warm water (fig. 7).

Fig. 7. — The sulphur and the iron have formed a new body : *combination*.

1. In a few minutes you see a great movement takes place; the little mass grows hotter, swells up and becomes blackish. *It now neither resembles sulphur nor iron.* **2**. Those two bodies are not merely mingled as they were a little ago: they are combined, and have formed a new body, which chemists call *sulphide of iron*. This time we are in presence of a **chemical** phenomenon.

There is another great difference between a *mixture* and a *combination*.

3. I may **mix** sulphur and iron in no matter what proportions. I can add one part, two or three parts of sulphur, or more. The mixture will simply be more or less rich in sulphur.

In a **combination** *this is impossible*. In order to have the combination of iron and sulphur I add 4 grains of sulphur to 7 grains of iron; the whole combined weighs of course 11 grains. That is not astonishing. But had I put together 5 grains of sulphur and 7 of iron, the sulphide of iron resulting from the combination would notwithstanding have weighed only 11 grains: 1 *grain of sulphur would have remained unemployed*, pure sulphur as before. Likewise had I put 8 grains of iron, one grain of iron would have remained over, and would not have combined with the rest.

4. Thus, *combinations* are unlike *mixtures* in this, that they are not indefinite or irregular; they cannot be obtained with various degrees of strength. **5**. For instance, in the case of sulphur of iron, no matter what quantity of

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1. What takes place if some warm water is added to the mixture of iron and sulphur? — 2. Is there a *mixture* or a *combination?* — 3. What else characterises mixture? — 4. What characterises a *combination?* — 5. Give an example.

iron and sulphur you mix together, the **sulphate** of iron obtained will always contain 4 of sulphur and 7 of iron. The *proportion* is, as chemists say, *definite*, or *determinate*.

I should like to see now if you have properly understood me.

Here is a glass filled with wine and water in about equal portions. Is this a *mixture* or a *combination?* **1**. It is a mixture, Sir, because one can add to the wine as much water as they like, it will always mix perfectly. — That is right, or in other words there is no definite proportion. Very well. What do you think, Paul; you do not seem convinced? — Sir, what puzzles me is, that I do not know how I could separate the wine from the water as you separated a little while ago the sulphur from the iron. I should have thought that the wine and water were combined. — **2**. Not so, my child, for one distinctive character of the combination is, that each of the bodies entering into it loses all its qualities, whilst the new body possesses new qualities. Recollect the sulphur and the iron on the one hand and the sulphide of iron on the other. In this glass, can you not recognise the wine and the water? Has the liquid acquired qualities belonging neither to wine nor to water? Assuredly not. Then it is decidedly a *mixture*, and not a *combination*.

3. This said, I will proceed to demonstrate that air is a **mixture** of two gases called *oxygen* and *nitrogen;* whilst water is a **combination** of two gases : *oxygen* and *hydrogen*. These are strange enough names. I will hereafter explain them to you.

Composition of Water.

We will begin with water. For one reason, because it is the most curious. Is it not strange indeed that this *pretty* limpid *liquid* should not in the first place be a *simple body*, and secondly that it should be composed of two *gases?* Yet so it is.

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1. Do *wine and water* form a mixture or a combination? — 2. Prove *that wine and* water form a mixture. — 3. What are the two gases that are mixed in the air? — What two gases are in combination in water?

197. Analysis by the electric pile. — You have not forgotten the rudimentary *electric pile* we made with pennies, and discs of cloth and zinc dipped in vinegar. I have made for this day's lesson several others like it, which I have united together so as to make use of the force of all of them at once (fig. 8). I immerse the two *poles* in this glass of water, which has been slightly salted or acidulated to allow it to *conduct* electricity with greater facility: **1.** After a few moments you will see tiny bubbles of gas forming on each pole, and rising to the surface; you have doubtless already observed also that these bubbles are not equally numerous at both poles. **2.** The two gases thus set at liberty are **oxygen** and **hydrogen**, the latter being the one that gives the greater number of bubbles.

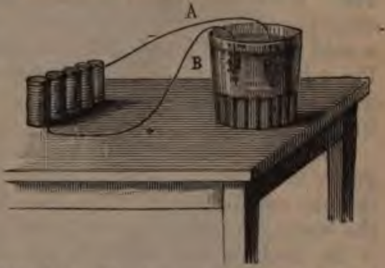

Fig. 8. — The two gases that you see rise to the surface of the water are *oxygen* and *hydrogen*.

Let us endeavour to catch some of each. For that purpose I take two small glass tubes CD (fig. 9) closed at one end; I fill both with water, and place one over each of the poles. The gas rises in each, but with greater rapidity in the tube D which receives the hydrogen, than in the tube C which receives the oxygen. **3.** It is easy to see at

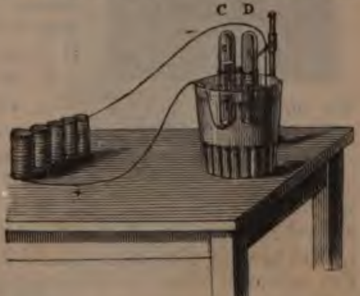

Fig. 9. — Two volumes of yhdrogen are formed in D, against one of oxygen in C.

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1. What takes place when the two poles of an electric pile are plunged into slightly salted or acidulated water? — **2.** What are the names of the two gases that are given off? — **3.** In what proportions are oxygen and hydrogen found in water?

a glance that the quantity of hydrogen discharged *is about double that of oxygen*, or, to speak more precisely, that there are *two volumes* of hydrogen for *one volume* of oxygen.

These gases are the result of the **decomposition of water**. If we had at our disposal a stronger pile, we could thus decompose all the water in our glass; and that would give us a pretty quantity of gas, I can assure you, for it has been ascertained that each cubic inch of water gives 1240 cubic inches of hydrogen and 620 cubic inches of oxygen.

198. Hydrogen. — While I have been speaking, the gases have almost filled up our little tubes, especially the one containing hydrogen, and I will withdraw it from the water, stopping up the opening with my finger. Here it is. I hold it with the opening downwards : Paul, will you light a match? All of you, be attentive. We had better go into a dark room (fig. 10). There now. I bring the lighted match close to the opening and take away my finger. **1.** Puff! a little noise and a pretty pale flame, giving so faint a light that scarce should we have seen it in the daylight.

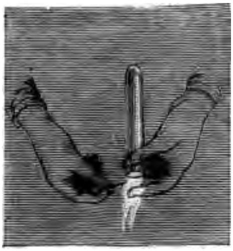

Fig. 10. — Puff! a little noise, and a little bluish flame. Hydrogen is then an *inflammable* and *explosive* gas.

2. Hydrogen is then, as you see, an *inflammable* gas, as chemists say, that means, a gas that can take fire. **3.** And if instead of having a small tube we had used a large flask of it, we should have caused a *real explosion*. **4.** Fortunately there is no hydrogen in the air, or else there would be no means of kindling fire without blowing every thing up.

5. Unfortunately however such accidents frequently happen in coal mines, where a gas, a near neighbour to hydrogen, *fire-damp*, sometimes issues from the coal. **6.** By

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1. What takes place when a lighted match is placed near a tube filled with hydrogen? — 2. What name is given to a gas that ignites in the air? — 3. What would have happened had the tube been larger? — 4. To what danger should we be exposed if hydrogen were in the air? — 5. To the presence of what gas are explosions in mines due? — 6. In consequence of what imprudence do these explosions result?

mprudently smoking or by opening their safety lamps, miners set fire to this gas, and fearful explosions are the esult (fig. 11). **1**. Another near relative of hydrogen

Fig. 11. — *Fire damp*, a near neighbour to hydrogen, produces, when inflamed, terrible explosions. It then combines with the oxygen of the air.

is the *gas* we burn, and with which our streets and houses are lighted (fig. 12); it is made from coal, and

Fig. 12. — The gas for lighting is another neighbour to hydrogen, and also presents dangers from explosion.

Fig. 13. — Balloons are filled with gas for lighting, which is three times lighter than air.

when conveyed in pipes from reservoirs, yields us incalculable services. **2**. It also is explosive. **3**. Its strong and disagreeable smell, however, betrays its

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1. Name another near neighbour of hydrogen. From what is the gas that we use for lighting streets made? — 2. What danger does it present? — 3. How do we know when there is an escape of gas?

presence and warns people of danger. **1.** On the contrary *hydrogen* when *pure* has no smell whatever, neither has *fire-damp*, and this is one of its great dangers. If chemists had been able to find out an inodorous gas for common use, as many tried to do, there would be no means of living with it, explosions would take place and houses be set on fire daily in all directions.

Hydrogen has still another characteristic. **2.** It is extremely light, **14 times lighter than air.** **3.** For that reason it was once much employed ***to fill balloons*** (fig. 13). **4.** Only as it cost a great deal to prepare, **common gas** is generally substituted for it. **5.** The latter is much heavier, or rather it is less light, since it is but **3 times lighter** than air; from this it follows that to be able to lift the same weight, the balloons must be much larger when filled with ordinary gas than when filled with pure hydrogen.

199. Oxygen. — But this is enough about hydrogen. Let us now look at our other tube C (fig. 9), which is almost full by this time : as we have already said, this one contains **oxygen.** You see it has no appreciable colour, no more than hydrogen or air. If I had enough to let you smell it, you would find it has no odour either; only as we possess but a very small quantity, we must economise it. I will forthwith show you its principal characteristic.

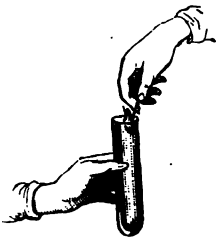

Fig. 14. — The match lights in the oxygen, this gas then keeps up *combustion.*

Paul, pray light a match. Now blow it out, and hand it me quickly whilst the end is still red. I plunge it into the tube, **6.** and, wonderful to be told, ***there it is lighted again,*** and burning as before (fig. 14).

7. This is the characteristic action of oxygen! It acce-

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1. What is it that renders the presence of fire-damp and hydrogen so dangerous? — **2.** Name a remarkable property in hydrogen. — **3.** How has the extreme lightness of hydrogen *been utilised?* — **4.** By what gas is *it now replaced* for filling balloons? — **5.** How many times is the ordinary gas less heavy than air? — **6.** What happens when a match, still red, is plunged into a tube filled with oxygen? — **7.** From this, what is the principal property of oxygen?

lerates, it revives fire, or, as chemists say, it *supports combustion.* It is under the influence of oxygen, for it exists also in the atmosphere, that our fires blaze and give heat, and that our lamps give light. **1**. *Our very life even depends on its presence,* our life, and that of all animals and plants; for every living thing breathes or wastes. We must however take things as they come, and we shall see about this in another chapter.

You plainly see the great difference that exists between hydrogen and oxygen. **2**. Hydrogen *takes fire and burns,* but it cannot set fire to the red end of the match plunged into it; oxygen, on the contrary, rekindles the half-extinct match, but *does not itself take fire.*

3. Chemists say that hydrogen is a **combustible** body, like wood, coal, oil, etc., whilst oxygen is but a **supporter** of combustion.

200. Synthesis of water. — Have you perfectly understood all this? I hope so. Now speak out, James. I see you wish to say something.

— Sir, you said that hydrogen takes fire, and afterwards you added that oxygen keeps the fire in. **4**. Is it then *oxygen that makes hydrogen burn?* — Quite so, my child; *were there no oxygen in the air, we should try in vain to kindle hydrogen.*

5. If a flame were plunged right into a vessel containing only hydrogen, great care being taken to avoid an explosion or at least a blaze in the introduction, the flame *would die out* for want of oxygen. Yes, Sir, but that is not what puzzles me most. When the hydrogen has blazed away, what becomes of it?

— That in fact is the knotty point. **6**. Hydrogen in burning *combines* with oxygen, just as you saw the sulphur combine with the iron. After the combination there remained neither sulphur nor iron, but *sulphide of iron.* **7**. Very well, *after the combination of hydrogen and oxygen, neither oxygen nor hydrogen remain.* What have we in their place? Who will answer that?

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1. How does oxygen affect the existence of man, animals, and vegetables? — 2. What great difference is there between hydrogen and oxygen? — 3. By what terms do chemists express these particular properties? — 4. In what manner does oxygen affect the combustion of hydrogen? — 5. Prove that it is oxygen that makes hydrogen burn. — 6. What does hydrogen form in burning? — 7. What remains after the combination of hydrogen and oxygen?

Nobody? Think a little. We have **decomposed** water into *hydrogen* and *oxygen;* now we **combine** ***hydrogen*** and *oxygen.* Ah! now you all find it out together. **Water!** Of course; but you should have thought of that sooner. You must try and keep your wits about you.

1. Yes, **water is made** again by burning hydrogen. And as there is hydrogen in almost all the bodies we burn, water is formed when they burn. **2.** Look at this cold plate, which I hold over the flame of my spirit-lamp (fig. 15). You see drops of water on it; don't be mistaken: this is not alcohol, distilled by the heat, taste it, it is merely water formed by the *combustion* of the hydrogen that existed in the spirit of wine.

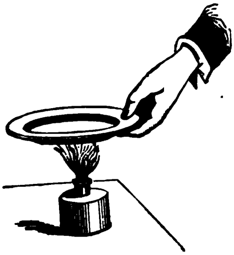

Fig. 15. — The water that condenses on the plate, is the water formed by the combustion of hydrogen that exists in the alcohol.

And now it is full time to tell you what the word *hydrogen* means. **3.** It comes from two Greek words : *hydor*, water, and *genao*, birth; it then means *a body that gives birth to water.*

Thus you see that the composition of water has been ascertained in two ways. First by *decomposition*, under the influence of the electric pile, into two gases, one of which, the hydrogen, is double the volume of the other (oxygen). Secondly, by *recomposition.* The water being obtained by uniting, either through heat or by some other means, two volumes of hydrogen with one of oxygen. **4.** This splitting up of a compound into its simple bodies is called *analysis*, and the building up of a compound from its simple bodies a *synthesis*, the recomposition.

Thus, if we put in a tube, a mixture of hydrogen and oxygen, in the proportion of one volume of oxygen for two of hydrogen, and then set this on fire, water will be formed, and the hydrogen and oxygen will no longer exist. But if we had put three times more hydrogen than oxygen,

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1. Why is water formed in the combustion of bodies that we burn? — 2. Prove it, by an experiment. — 3. What is the signification of the *word hydrogen?* — 4. What do chemists call the decomposition of bodies into their simple elements? — What is the recomposition of compound bodies called?

what would have happened, George?—There would have been too much *hydrogen, and some would have remained over.* — How much? — One portion. — You mean one *volume*, that is right. In like manner some oxygen would have remained unemployed had we put in the first mixture more than the necessary proportion.

In short, water is a *combination* of hydrogen and oxygen in *definite proportions*, as is the case with all chemical combinations.

Composition of Air.

201. Composition of air. — Let us now pass to the study of *air*. I have already told you that **oxygen** enters into its composition. We have already made acquaintance with this gas in our lesson on water. You remember we saw it inflame hydrogen, thereby giving birth to *water* and sulphur, thereby making *sulphurous acid.*

But air is not solely composed of oxygen. The proof of this is, that the end of a match, newly blown out and still red, does not light up again in the air, whilst we saw it do so in pure oxygen. 1. In atmospheric air there exists only about a **fifth** part of oxygen; *the rest is a gas called nitrogen.*

202. Nitrogen. — Paul, how would you go to work were I to bid you prepare some nitrogen, I mean, to separate it from the oxygen of the air?

I should add hydrogen to the air; then set it on fire; the hydrogen would take up the oxygen, as you said, and form water, leaving the nitrogen alone.

— Well imagined, very well indeed, my dear child. But the plan would be very difficult to put into execution, and very expensive; yet it could be done, if one had the necessary apparatus. You, James, have you found anything?

— Sir, I would set fire to some sulphur under a glass shade; the sulphur would absorb the oxygen and set the nitrogen at liberty. It is the experiment you made a little while ago.

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1. What are the gases that enter into the composition of air? — In what proportion are these two gases mixed?

— Quite so. But that would not give you pure nitrogen: the sulphur would not burn up all the oxygen of the air. The experiment has indeed been made in that manner; but it is another body, *phosphorus*, not sulphur, that is employed.

203. Preparation of nitrogen by phosphorus. — I have a little bit of this phosphorus, so we will try. I am obliged to keep it under water, as you see, because it is rather dangerous and takes fire as soon as it is in contact with the air. So, as quickly as possible, I put it on this bit of earthen ware, this again on a piece of wood, the wood on the water, and a globe over the whole (fig. 16).

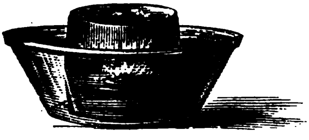

Fig. 16. — Nitrogen remains after the phosphorus by burning has taken up the oxygen of the air.

Let us now pass into the dark room. You see the phosphorus is luminous as soon as it is in air, and you all recognise the light it emits to be the same as that given by matches when rubbed on any thing in the dark, for matches are made with phosphorus and divers ingredients. You can see also that *phosphorus* well merits its name, for the word means *light-bearer.*

Now let us return to the school-room. Our bit of phosphorus after having emitted a good deal of white vapour, all at once bursts into a flame. See how pretty it is. **1.** Who would fancy that *such a thing should be extracted from the bones of animals?*

On account of the strong heat of the burning phosphorus some air escapes by expansion from under the shade. See now, the flame dies away, the air cools, the water rises and stands still. *The gas remaining in the shade is* **nitrogen** with a very little oxygen. If the phosphorus be left under the shade until it be no longer luminous even in obscurity, the very last traces of oxygen have been exhausted. For this dim light is in reality *slow combustion,* whilst what we saw a little while ago was *active combustion.* You see there are different degrees of combustion; but they all come to the same result.

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1. *How is* phosphorus obtained?

204. Oxygenised compounds of phosphorus. — It is now the turn of nitrogen to be examined. But, before setting to work, please, Paul, would you tell me what has become of the phosphorus? — Sir, *it has combined with the oxygen of the air*, as the sulphur did a little ago. — Well. And what did it form? As the sulphur forms sulphurous acid, the phosphorus ought to form *phosphorous* acid. — Not precisely, it forms *phosphoric* acid.

— Please, Sir, what do the terminations *ic*, or *ous* mean? You have already spoken about *sulphurous* acid and *sulphuric* acid.

That will be easily explained, my dear children. Sulphur, phosphorus, and many other bodies, can combine with oxygen in different proportions so as to form *several acids*. Hence the necessity of giving different names in order to recognise them, and yet those names must resemble each other, being given to different compounds of the same bodies. **1.** Thus the termination of *ous* was given to the acid containing the *smallest quantity of oxygen*, the termination *ic* to that containing the *greater*.

For instance, when the phosphorus burns brightly, it makes *phosphoric* acid; when it burns slowly, it gives *phosphorous* acid, less rich in oxygen.

205. Properties of nitrogen. — And now to nitrogen. Here is a live mouse in a trap. I pass the whole rapidly under water into the nitrogen (fig. 17) our experiment gave us. **2.** Immediately you see the mouse looks agitated, falls down and gasps; it is dead, *asphyxiated* as people say. **3.** *It is not the nitrogen that has killed it, it is the want of oxygen.* Nitrogen is by no means a poison, for we breathe it in breathing the air in which

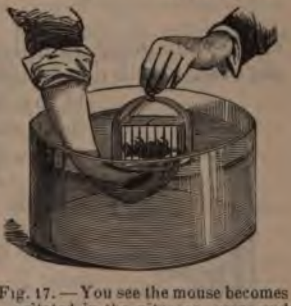

Fig. 17. — You see the mouse becomes agitated in the nitrogen, gasps and dies. The want of oxygen has killed it.

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1. To what kind of acids do we give the termination *ous*? And the termination *ic*? — **2.** What happens when an animal is plunged into azote? — **3.** Is then azote a poison? — Prove it. — Why then did the mouse die?

we live, but it perfectly merits its *original* name *azote*, which means, in short, *incapable of sustaining life* (*a*, which expresses negation, and *zoe*, life).

Thus *life dies out in nitrogen.*

Combustion also dies out therein. Only how shall we be able to prove this last affirmation? It is impossible to pass a lighted match through the water, as was done with the mouse: it would be extinguished before getting near the nitrogen. We must have some nitrogen in a tube, as we had the other gases a little time ago.

There is no great difficulty in this. Let us take our basin out into the court-yard and put it in the water trough. We will set it quite in the bottom of the basin, shade, mouse, cage and all. You, James, hold the shade containing the nitrogen, and keep it in the water C (fig. 18), mouth downwards of course. I adapt a funnel to my little tube, fill with water both tube and funnel, and immerse the whole, the funnel undermost (fig. 19). Now, James, incline your shade slightly to one side, in the direction of the funnel. See, *the nitrogen passes into the funnel and fills the tube* D. There, the operation is successfully terminated.

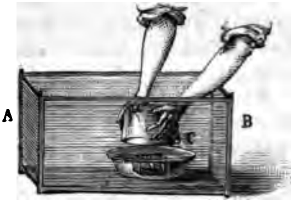

Fig. 18. — Hold the shade C full of nitrogen.

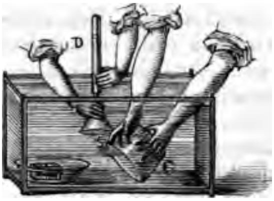

Fig. 19. — The nitrogen passes from the shade C into the funnel and fills the tube D.

Now, stopping up the opening of the tube with my finger, I take it out of the water, still holding it inverted. This time we will put into it a well-lighted match (fig. 20). See, *it goes out immediately.*

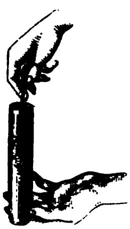

Fig. 20. — The match goes out in the nitrogen. So this gas does not support combustion.

That is enough I should fancy to convince you that nitrogen does not support *combustion*.

206. Air is a mixture, not a combination. — There is, as I told you, about 4 *fifths of nitrogen in the air*. This is not the exact proportion. The exact numbers are 79.2 per cent for nitrogen, the proportion of oxygen being 20.8 per cent.

This makes one volume of oxygen against 3.80 of nitrogen, and in weight 1 of oxygen against 3.348 of nitrogen.

1. I moreover told you that air is simply a *mixture* not a *combination*, and I am sure you will have no difficulty in following my explanation as to the reason.

2. In the first place those complicated numbers and fractions differ widely from the *simplicity* of the proportions often found in combinations. You recollect, in water there are two volumes of hydrogen to one of oxygen, and in weight 1 of hydrogen to 8 of oxygen. In weight again, for sulphur of iron, 4 of sulphur, 7 of iron; for sulphurous acid, 1 of sulphur, 1 of oxygen; for sulphuric acid, 2 of sulphur, 5 of oxygen; for phosphorous acid, 4 of phosphorus, 3 of oxygen. **3.** In a word, as I have already said, in all **combinations**, the component bodies are not only in *definite proportions*, but also *in simple ratio:* **4. Mixtures**, on the contrary, have not *any ratio whatever*, and are sometimes exceedingly complicated.

Secondly, the composition of air can be altered with great facility. If, while the phosphorus was burning a little ago, I had allowed it to fall into the water, the air remaining under the shade would have been less rich in oxygen than common air, and the longer the experiment would have lasted, the less oxygen would there have been. There are not then any *definite proportions* in the composition of air, as there are in chemical combinations.

Again, air has at the same time the properties of oxygen and those of nitrogen. It supports the combustion of bodies, under the influence of oxygen, only with less energy on account of the influence of nitrogen. Whilst you know that in a combination, that of water for instance, the distinctive or specific properties of hydrogen as well as those of oxygen have disappearedf

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1. Is air a mixture or a combination? — 2. Why do you suppose it is a mixture? — 3. In what manner do the compound bodies act in a combination? — 4. In a mixture?

So, once more I repeat, air is a *simple mixture* and in no sense a *combination.*

Now we are beginning to see a little into chemistry since we have learned what *air* is and what *water* is, this being no light matter. 1. We also know about *oxygen, hydrogen,* and *nitrogen,* three of the simple bodies found in a gaseous state. The fourth, by no means void either of interest or of utility, is *chlorine,* only its study would encroach too much on our time.

But we must not boast about what we have learned. How many bodies yet remain unknown to us! Not only simple, but also compound bodies, composed of 2, 3, 4 or more simple bodies! We could never think of learning all about all these, nor even could we pass in review an insignificant part of them. Notwithstanding, I have yet to tell you about several very interesting things, which you will find prove useful to you in many respects.

Carbon.

207. Carbon. — In the first place we will occupy ourselves with the study of *charcoal.* **2.** Charcoal is an impure form of *carbon.*

208. Composition of vegetable matter. — **3.** You are all aware that charcoal is derived from plants, from *wood* burned in a certain smothered manner. This shows of course that carbon exists in plants, since it is extracted from them.

Indeed it exists in all their parts, in their wood, their leaves, their flowers, etc. And you will no doubt be astonished to learn that carbon is there combined with hydrogen and oxygen. **4.** *It is these three bodies,* **carbon, hydrogen,** and **oxygen,** *that when united form almost all kinds of vegetable matter.*

See, here is a bit of sugar; a substance derived from a plant. **5.** I put it on this red hot shovel (fig. 21) keep-

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1. Of the four simple gaseous bodies which are the three known to you? — 2. What is charcoal? — 3. From *what is it derived?* — 4. What are *the three bodies* that form vegetable matter? — 5. What becomes of a piece of sugar on a red hot shovel when it is prevented from catching fire?

ing it from burning with a flame; finally there remains nothing but very pure and black carbon. **1**. If, while it is burning, I hold a cold plate (fig. 22) above it, you will there see water condense upon it. This water is produced by the combination of *the oxygen and the hydrogen of the sugar*.

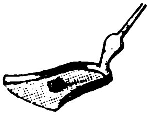

Fig. 21. — On the red hot shovel the sugar only leaves a very pure black carbon.

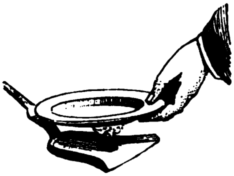

Fig. 22. — The water produced by the combination of oxygen and hydrogen of the sugar, condenses on the plate.

2. Starch*, gum* arabic, alcohol*, oils* and almost all substances of vegetable origin, will give the same result.

See what a variety of forms nature gives to these **three simple bodies**, carbon, hydrogen and oxygen.

209. Composition of animal matter. — **3. Carbon** exists also in the different parts of the **bodies** of animals. **4**. What is known under the name of *animal black*, is a *charcoal*, obtained by the calcination* of bones in close vessels.

5. In *animal fat* also, hydrogen and oxygen combine with carbon just as in vegetable oil. **6**. In all the parts of the body, such as the flesh, the brain, etc., excepting in the fat, these constituents are found in combination with nitrogen. *And it is with these four simple bodies variously combined that all the different constituents of animal bodies are formed.*

7. Three are, as we have seen, gaseous; the fourth, *carbon*, is a solid body.

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1. How do you prove that the sugar contains something else besides carbon? — 2. What is starch composed of? — Gum Arabic? — Alcohol? — Oils? — 3. Where else is carbon found? — 4. What is animal black? — 5. What is the composition of *animal fat?* — 6. What is the fourth body that enters into the constitution of, say the flesh and brain? — 7. Of the four simple bodies, that form the bodies of animals, which are the three gaseous ones? — Which is the solid body?

210. Various forms of carbon. — And now let us examine carbon itself. It enters as we have said into the composition of *wood, charcoal, and animal black.* Do any of you remember to have met with it under any other form? — Yes, sir. — *Coal and coke.* — Ah! is coke the same thing as coal? — No, sir; coal is greasy and *shiny*, whilst coke is quite dry. — Yes, those are apparent differences, but do you remember nothing more striking? What do you think, Henry? as you have lived in town where the streets are lighted with gas, you know perhaps the difference between coal and coke. — Yes, sir; *coke is that which remains, when the gas that lights the streets has been taken* from *the coal.*

1. Quite right, my child; when the coal is sufficiently heated, the gas is set at liberty and along with it many other things, *for it is marvellous what can be extracted from coal:* rich colours, delicate perfumes, nearly a hundred useful substances, and amongst them flavours for sweetmeats. **2.** So you see coal is not pure carbon, far from it; *but that which remains after it has been heated, that is to say coke, is almost pure carbon.*

Carbon is found under other forms still: **3.** *Black lead* as it is very improperly called, of which your pencils are made, is almost pure carbon. It is found in certain mines, and is called also *plumbago and graphite.*

4. But what is most curious, is that the **diamond is pure carbon.** I mentioned the fact when speaking about different crystals. Yes, it is quite true, that beautiful stone, so brilliant, so transparent, so hard that it can cut or engrave any thing however hard, *has the same chemical composition as that ugly bit of coal,* black and friable*, sold in cart-loads for a few shillings. You cannot believe such a thing, and your very eyes demand proofs of it; oh! I am quite prepared, do not be afraid.

211. Products of the combustion of carbon. — **5.** First, if a diamond be heated to a high temperature, it swells out, and is transformed into a substance very similar to coke. This however may pass for mere

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1. What do we obtain from coal? — 2. What remains after the gas has been extracted from coal? — 3. Name another form of carbon. — 4. What is the diamond? — 5. Give me a proof that the diamond is carbon.

external resemblance, and might be disdained as proof of chemical identity.

Here is a lump of coal, I put it on the fire. It reddens, burns away and disappears, as you all know, leaving only a few cinders, which are but impurities and have nothing to do with carbon. The latter has disappeared, it has burned; but what has become of it, for nothing can be lost? It has *burned*, that means that it *has combined with the oxygen of the air*, has it not?

This combination can give rise, according to circumstances, to two sorts of gas.

1. When *coals burn brightly and with strong heat, they form* **carbonic acid,** in which there are 3 parts of carbon for 8 of oxygen. 2. *When they burn slowly and dimly, they form* **carbonic oxide,** in which there are 3 parts of carbon against only 4 of oxygen.

3. In our fire-places, the coal in burning gives off a mixture of *carbonic acid gas* and *carbonic oxide.* 4. The more draught the chimney gives, the brighter the fire burns, and the more active the oxidation* and the less carbonic oxide gas produced.

You ought now to sufficiently understand the real chemical characters of carbon. You may burn coke, animal black, graphite (plumbago), or diamond, you will always have carbonic acid or carbonic oxide gas given off, according to the greater or less energy of the combustion.

5. And you will have, at least in the case of graphite (plumbago) and of the diamond, for those will not leave even cinders, only and solely gas, as product of the combustion. Thus *all these bodies are carbon,* pure carbon even, especially *graphite* and *diamonds.*

Now the *carbonic oxide* and the *carbonic acid gases* formed in our fire-places and stoves, or emitted by our lamps and candles, merit our attention.

212. Carbonic oxide gas. — We will begin with the *carbonic oxide gas.* 6. It is a colourless

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1. What gas is formed when coal burns brightly and quickly?— 2. And when it burns slowly? — 3. What does coal form while burning in our fire places? — 4. What happens when the fire burns brightly? — 5. Give a second proof that the diamond is pure carbon. — 6. What do you know of the carbonic oxide gas?

and inodorous gas when mingled with the air, and this is very much to be regretted, *for it is a most deadly poison.* 1. A *thousandth part* of this gas in the air suffices to cause death in a very short time; a *ten thousandth* part is enough to give violent **headaches.** 2. You see how very important it is for our health and even our life *that the product of combustion* should escape easily and with certainty from our dwellings* by the chimneys. 3. The small stoves in which charcoal is often burned give a large proportion of **carbonic oxide,** hence *headaches, pallor,* and *even dangerous illnesses.* 4. I will not leave this subject without warning you against a very imprudent habit some people have of taking *into a bed room a stove* or something similar containing *charcoal or red embers of any kind.* A severe and dangerous headache is the least that can happen, and journals often tell sad stories of fatal results to those who try to keep themselves warm during their sleep in this imprudent manner.

213. Carbonic acid. — Oxide of carbon can be set on fire and burned like hydrogen, it then forms what, Paul? — *Carbonic acid,* Sir. Perfectly so, the oxide of carbon combines in a new proportion with oxygen borrowed from the air. It burns with a pretty pale blue flame, which you can see dancing up and down on the charcoal I have lighted in this little stove. Unfortunately a great part of the carbonic oxide is not consumed, but escapes into the air.

In short, carbonic acid can be formed in two ways during combustion; either at the first onset, by direct combination of the carbon with a considerable quantity of oxygen; or by a twofold action by the combustion of oxide of carbon that has been previously formed. All this is continually going on in our fire-places, and this it is that gives us heat.

Carbonic acid is also a colourless gas, which has little

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1. What effect is produced by the 1000th part of oxide of carbon in the air? — By the ten thousandth part? — 2. *How then* ought our fires and firesides to be arranged? — 3. What gas escapes from charcoal stoves? — 4. What precaution is it necessary to take?

if any odour. 1. It is much less dangerous then carbonic oxide, and it only becomes seriously so, when there is about 20 per cent. in the air. But people should notwithstanding be very cautious with carbonic acid, and that for two reasons.

In the first place, I do not think it would be at all healthy for a person to remain in a place where the air contained 4 or 5 per cent. of carbonic acid; but this is not all.

When there is carbonic acid in a room, it is not because some chemist has brought it there, to mix with the air of the room. Of course not, it was formed there. 2. And at what expense. Undoubtedly at the expense of the *oxygen of the air.*

Now carbonic acid is so composed, that it contains a volume of oxygen equal to its own volume. 3. Then if there exist in a room ten per cent. of carbonic acid, ten per cent of oxygen for that reason is wanting: instead of the 21 per cent. that ought to be forthcoming in wholesome air, 11 only remains. You understand that a person under such conditions incurs double danger; firstly in breathing the air poisoned by the carbonic acid, secondly, running the risk of being asphyxiated for want of oxygen. This might very easily happen to us without using charcoal or anything of the kind; all that we would have to do would be to shut everything very close, and all of us to remain here in the school room. How so? you may ask. 4. Ah! we also *absorb oxygen and give back carbonic acid.* Our body **burns** in its interior, just as the bit of wood burns in the chimney; only quite slowly, and yet without forming carbonic oxide. But here we put foot on another territory. We shall see about this when we come to speak of *animal physiology.*

5. Carbonic acid is not formed only in our fireplaces and in living bodies. In certain countries it oozes abundantly out of the very earth. In the island of Java there

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1. What quantity of carbonic acid in the air produces death? — Compare it with the oxide of carbon. — 2. At what expense is carbonic acid formed in a room where we breathe? — 3. What happens when there is ten per cent of carbonic acid in a room? — 4. What takes place in regard to the respiration? — 5. Name some examples of the natural formation of carbonic acid.

is a valley in which the soil emits such quantities that nothing can ever live within its bounds, and the very birds that venture to fly over it fall down overpowered and die. Near Naples*, at Pozzuolo, there is a grotto (fig. 23) in which a man can walk without danger, but into which a dog cannot enter without being asphyxiated by the carbonic acid that escapes from the soil. You ask why there is danger for a dog whilst a man is in safety. It is because the carbonic acid being heavier than the air remains low down near the ground.

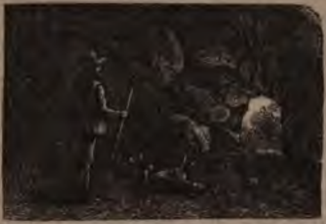

Fig. 23. — Carbonic acid spread on the ground kills the dog, but does not act upon the man.

1. Carbonic acid is also formed *during the fermentation* of beer* or of wine**. Hence the danger of making wine or beer in insufficiently ventilated places (fig. 24).

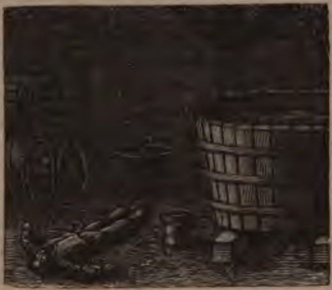

Fig. 24. — Carbonic acid is formed in the fermentation of beer and wine.

2. After all this you will not be astonished to learn that there exists a little carbonic acid in the air, in variable proportions, but always under 1 per thousand.

214. Carbonate of lime. — 3. Carbonic acid is nevertheless very frequently met with in nature, not free however, but in *a combined state.*

I will again have recourse to an experiment that has already proved useful to us more than once. Here is a bit of *lime* stone.* I put it in a glass and pour strong

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1. Under what other circumstances is carbonic acid formed? — 2. In what *proportion is carbonic* acid mixed in the air? — 3. Under what form is carbonic acid frequently found in nature

vinegar (fig. 25) over it. 1. You see it gives off bubbles of gas: *this gas is carbonic acid that the vinegar has set free.*

Fig. 25. — From the calcareous stone the carbonic acid escapes which the vinegar had set free.

With what was the carbonic acid united? With the *lime,* we have already learned that. If we had submitted the stone to a very strong heat for a good length of time, the carbonic acid would have been set free, and the lime only would have remained, and therefore had it subsequently been put into vinegar no effervescence would have ensued.

2. Chemists give to the combination of this calcareous substance the name of *carbonate of lime,* which name indicates that *carbonic acid* and *lime* enter into its composition.

215. Synthesis of carbonate of lime. — Before leaving this subject, let us do as we did when studying water. We have decomposed it by analysis, let us reform it by synthesis.

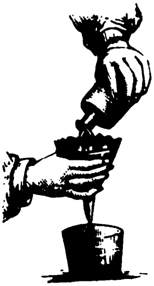

Fig. 26. — The liquid that passes is limpid still, there is in it a little dissolved lime, lime water.

There is nothing easier. We will throw into a glass of water this little bit of lime, but we must take care, for it is lime recently made, *quick lime* as it is called, and will impart no little heat to our water. There now it is quieter and a part of the lime is dissolved. In order to separate this liquid part from what has settled down at the bottom of the glass we will filter it through some blotting paper folded and placed in the funnel (fig. 26). See how limpid it is as it runs through. Yet it contains lime in solution, and is what is called *lime water.*

Now in order to form carbonate of lime with this lime water what must we add to it? Carbonic acid. Yes, but how could you do so, what do you think, master Paul; Well, Sir, I should take a pair of bellows and go and fill

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1. How do you prove that a calcareous stone contains carbonic acid? — 2. What name do chemists give to the combination of carbonic acid and lime?

the bellows over the fire place where the carbonic acid escapes from the combustion of the coal, then I would blow the contents of the bellows into the glass of lime water. — Very good, very well thought of; but if we had no bellows, or if there were no fire, what then, what would you do, James? — I have heard papa say there was carbonic acid in soda water; I would just put soda water into the lime water. — Very true there is carbonic acid in soda water; and it is this gas that escapes when the bottle is opened. Ah! I see George has found something. Speak out. — Why, sir, *since we ourselves produce carbonic acid* by *breathing, we should only have to blow our own breath into the lime water;* that is easy enough. — Well answered, as you say it is easy enough, the difficulty was to find the idea. And to reward you for your sharpness, I will beg you to make the experiment yourself. Blow into the water through this straw (fig. 27). Do you see how the water becomes turbid and thick looking as if you had poured milk into it. **1**. This change is produced by the presence of **carbonate of lime** *formed by the lime in solution in the water and the carbonic acid* passed into it, George. **2**. This then is the *synthesis* of carbonate of lime.

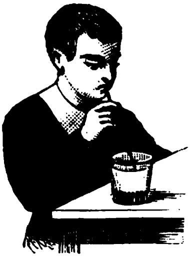

Fig. 27. — The lime water becomes troubled. It is because George in blowing into it carbonic acid, formed carbonate of lime.

Let it settle down in the glass. At the end of the lesson we will pour off* the water; and then if we add some vinegar, we shall see the carbonic acid furnished by George's lungs rising in bubbles to escape.

Oxides, Acids and Salts.

216. But we have not yet quite finished with *carbonate of lime,* it will still afford us several important facts. As we have already said and seen, *carbonic acid* and *lime* enter into its composition. Carbonic acid, we

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1. What happened when George blew into the lime water? — 2. What name do chemists give to this recomposition of carbonate of lime?

know, is composed of 3 parts of carbon to 8 of oxygen. But what is lime? Is it a simple body? No, it is a compound body. Composed of what? 1. Of **oxygen** again, and a simple body, a metal from which it is very difficult to separate it, this metal is called **calcium**. 2. Chemists say that lime is an *oxide of calcium.*

217. Metallic oxides. — 3. *Oxygen combines in like manner with all metals, thus forming* **oxides.** This takes place with more or less ease and rapidity; but it always does take place. 4. If we had at our disposal some *calcium,* and were we to expose it to the air, it would rapidly absorb oxygen, so as to become *lime.* 5. More than this, were it thrown into water, it would forthwith decompose it, so as to take hold of the *oxygen* it contains, expelling from its combination the hydrogen. This then is a metal which is easily oxidised.

Let us now cast a glance at **iron.** As you well know, it can be left exposed to the air, without fear of immediate injury. 6. Yet in the long run, if the weather be dry, or if it be left a few days in the damp, it undergoes considerable alteration; it *rusts.* Chemists say it oxidises. *And in reality it absorbs oxygen from the surrounding air,* and the reddish powder that you all so well know is the result of that combination. 7. Rust is then an *oxide of iron.*

Now let us look at **copper**. It can remain still longer than iron in contact with the atmosphere without undergoing alteration. Nevertheless in the end, under the influence of damp it also will *oxidise* and form a greenish body called *verdigris.* 8. This verdigris is *an oxide of copper.*

9. We must now study **mercury,** that silvery *liquid* metal I showed you in explaining the construction of barometers. We might leave it no matter how long in contact with air, and yet detect no alteration. 10. But were we to make it boil for some hours, we should see its

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1. Of what is lime composed? — 2. What name do the chemists give to lime? — 3. What combination does oxygen form with all other metals? — 4. What would happen to calcium if exposed to the air? — 5. How does calcium act in water? — 6. What happens to iron when exposed to the air? — 7. What is *rust?* — 8. What effect has damp air upon copper? — What is verdigris? — 9. What is mercury? — 10. How can mercury be oxidised?

surface covered over with reddish powder, this is *oxide of mercury*.

1. Lastly, **silver**, which *never oxidises by contact with the air*, rusts neither by cold nor by heat; no more does **gold**. Chemists however are able, and that without difficulty, although by indirect means, to obtain *oxide of gold* and *oxide of silver*.

This more or less rapid oxidation by the simple contact of air explains *why some metals are very frequently found in the earth in their* **natural state,** *whilst others are always found in the state of oxides*, or in combinations more complicated still.

2. Thus gold, silver, platinum, mercury and copper, are frequently found in the soil in a metallic or *native state*, that is to say, *pure*. **3**. *Native iron* on the contrary is very rare. **4**. Zinc, tin, lead, are always combined either with *oxygen or* with *sulphur;* but as they neither oxidise very rapidly, nor have great affinity for oxygen, it is not very difficult to extract from them the oxygen with which they are naturally united.

5. It is of course quite otherwise with metals that have great affinity for oxygen, *calcium* for instance. They are never found in a native state. And it is moreover extremely difficult to extract their oxygen and bring them to a metallic form. Even the hottest fire fails to attain this result.

6. From time immemorial*, *lime* has been known: but it is not until very lately that *calcium* was extracted from it; this was obtained by the decomposition of lime under the influence of a strong electric pile. In like manner *potassium* has been extracted from *potash*, *sodium* from *soda*, *magnesium* from *magnesia*, substances with which chemists have been acquainted for many a day.

7. In short, in one way or another with more or less difficulty, all *metals* combine with oxygen and so form *oxides*.

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1. For what property are gold and silver distinguished? — 2. Name some metal that are frequently found in the earth in their *native* state. — 3. Mention a metal that is rarely found *in its native state*. — 4. In what condition are zinc, tin, and lead, found? — 5. What happens to metals that have a strong affinity for oxygen. — 6. Name some metals from which it has only lately been possible to extract their oxides. — 7. To sum up: what do all metals form in combining with oxygen?

218. Non metallic oxides. — **1.** But **oxygen** also combines, as we have already seen, with bodies that have neither the weight, the brilliancy, nor the other qualities of metal. **2.** Thus we learned that it combined with **carbon**, and formed *carbonic oxide* and *carbonic acid.*

3. With **sulphur**, it forms *sulphurous acid* and *sulphuric acid.*

4. With **phosphorus**, it forms *phosphorous acid* and *phosphoric acid.*

5. I might tell you also that it combines with **nitrogen** in a real combination, not a mixture as in air, thus forming divers *oxides,* the most important of which are *nitrous acid* and expecially *nitric acid,* sold under the name of *aqua fortis.* **6.** This last named is extremely dangerous, burning horribly; the slightest touch of it stains the fingers with ugly yellow spots.

219. Acids, bases. — In most cases the compounds of acids with metals are called oxides or bases.

Thus, potash, soda, lime, magnesia, the oxides of iron, copper, etc., are bases.

The compounds that oxygen forms with non-metallic bodies are generally called acids : we have already heard of carbonic acid, azotic acid, sulphuric acid, etc.

But you must moreover know that some bodies are called acids and bases although they contain no oxygen.

For instance, alkali, or, as it is called in chemical language, ammoniac, is a compound of nitrogen and hydrogen, notwithstanding it is a base.

And again hydrochloric acid is a compound of chlorine and hydrogen only; this is likewise the case in sulphydric acid (that which gives the noxious smell of rotten eggs), it contains only sulphur and hydrogen.

It is for no capricious reason that chemists have arranged things as they are. But it would be almost impossible for me to explain clearly to you what induced them to have done so.

I must however acquaint you with another character which causes a body to be called acid or alkaline.

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1. Does not oxygen combine with metals? — 2. What compounds does it form with carbon? — 3. With sulphur? — 4. With phosphorus? — 5. With nitrogen? — 6. What do you know of nitric acid, or aquafortis?

I add to this glassfull of water a few drops of ammonia. I then dip in it this slip of blue paper that has been coloured by tincture of turnsole: the paper remains of the same colour as before.

In this other glass, I have added to the water some drops of sulphuric acid. I dip into this glass also a similar little slip of blue paper. See, it has immediately become red. If I now replunge it in the glass with the ammonia, it will forthwith resume its blue colour.

Hence it is said that acid substances redden the turnsol dye, whilst alkaline substances bring back the blue colour. All colours obtained from plants are modified in like manner by acids or by alkaline substances.

I will now show you a very curious experiment. See, I take our pile, a glassfull of water and two tubes, and I dispose the whole as we did when we decomposed the water. (See p. 241, fig. 9.) Only I add to the water some drops of tincture of *turnsole,* which gives a blue colour, and a small quantity of a body called sulphate of soda.

There, the electric current passes. You see that in the tube in contact with the positive pole, from which oxygen is given off, the water becomes red; in the other tube, on the contrary, the water remains blue.

So, when a body is decomposed by means of an electric current, *the acid goes to the positive pole, the base, or alkaline constituent, to the negative* **salts. 1.** Bodies composed of an acid and a base are called salts.

There exist of these, as you may easily fancy, a great number, since about fifty metals are known to be capable of giving bases. I must mention a few of the most important.

In the first place, there are the *carbonates:* carbonate of lime, that has already so often come under our notice; carbonate of potash, which is to be found abundantly in wood ash; carbonate of soda, which is used in a crystallized state for household purposes. Carbonates are easily recognizable by the fact that from whatever acid they be derived, when decomposed, their carbonic acid escapes under a gaseous form.

Then we have the *nitrates.* The most interesting of these is nitrate of potash, or saltpetre, which is to be

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1. What name is given to the compounds of an *acid* and of *oxide* or *bases?*

found on old damp walls. It is used in the fabrication of gunpowder, and is then mixed with sulphur and with carbon.

Several sulphates have considerable practical interest. For instance *sulphate* of *lime*, otherwise called plaster, which we have already mentioned (See p. 120), sulphate of soda, and sulphate of magnesia, much used for medical purposes; sulphate of iron (green vitriol), and sulphate of copper (blue vitriol).

Amongst *phosphates*, the phosphate of lime is one of the constituents of bone, and is much used in agriculture.

The *silicates* hold an important place in nature : silicious stones (slate, argil or clay, granite, quartz) are therewith composed.

Another category of salts is formed by acids that contain no oxygen. (Those best known are the *chlorides* and the *sulphurets*).

Sea salt is a chloride of sodium, that is to say, a compound of chlore and of sodium : two bodies only.

You can see the difference between these and the other salts which we considered a little while ago, such as, for example, the carbonate of lime, in which exist 1. carbonic acid (carbon and oxygen), 2. lime (calcium and oxygen): in short, three bodies.

Metals generally used. — The most important of these is *iron*, whose general use is greatly facilitated by its property of being welded, when reddened in the fire.

When heated by very intense fire and brought to a very high temperature it becomes sometimes cast metal, sometimes steel.

You all know the many different uses made of iron and other much-employed metals, such as copper, lead, tin, zinc, silver, gold, mercury.

In some circumstances, you know, several are mingled together so as to form the alloy necessary for industrial usages : such are brass, alloy of copper and zinc, such are also the bronzes, alloy of copper and tin in different proportions.

The greater number of these metals I have first mentioned, have been know in ancient times. I have already told you that some, such as gold, are found in a pure state amongst sand or in rock, from which they are easily extracted. Others, and these are the more numerous, exist in the shape of oxides, sulphurets, or carbonates.

In these two last cases, they are roasted in contact with the air; the sulphur or carbonic acid escapes, and the metal remains.

As for the oxides, they are mingled with the coals and submitted to intense heat. The coal lays hold on the oxygen of the metal, thereby forming carbonic acid and carbonic oxide, both of which escape, leaving the metal alone.

It is after this manner that iron is treated in *blast furnaces*.

Metals may be by divers processes applied one upon another. A thin coating of gold or silver may be laid on any other metal, etc. This is called gilding or silvering. Wires are also in like manner coated, so as to prevent rust; cooking utensils inlaid with tin, so as to avoid verdigris, etc.

But many more interesting things might I tell you about metals, had we time.

SUMMARY. — CHEMISTRY.

1. **Simple bodies and compound bodies** (p. 235-237). — Bodies that cannot be decomposed are called *simple bodies*.

2. *Compound bodies* are those in which there exist several simple bodies **combined** together.

3. 70 simple bodies are known at the present day.

4. All metals enter into this category.

5. The greater number of simple bodies are *solids;* such are gold, silver, iron, copper, zinc, lead, tin, sulphur, carbon, phosphorus, arsenic.

6. Two are *liquids*, one of which is mercury.

7. Four are *gaseous*, these are oxygen, hydrogen, nitrogen, and chlorine.

8. **Mixtures and chemical combinations** (p. 238). — There is a very great difference between a *mixture* and a *chemical combination.*

9. In a **mixture** the nature of the bodies mixed together remains unaltered, and the mixture can be made in *any proportion whatever.* The phenomenon is purely *physical.*

10. In a **chemical combination** the nature of the bodies present is totally changed, and the union of those bodies takes place in *simple* and *definite* proportions.

11. Air is a *mixture;* water is a *combination.*

12. Water (p. 240). — Water is a *combination* of two gases the one called **hydrogen**, the other **oxygen.**

Water may be easily *decomposed* under the influence of the electric current, this decomposition gives one volume of oxygen for two of hydrogen.

13. Hydrogen (p. 242). — Hydrogen is an inflammable gas.

14. If a mixture of *air* and *hydrogen* be set on fire, an **explosion** ensues and water is obtained.

15. This happens in coal-mines, where *fire-damp*, a near neighbour of hydrogen, escapes from the coal.

16. Gas. The gas we burn is another relative of hydrogen; when mingled with air and set on fire, it causes the same danger of **explosion.**

17. Hydrogen is 14 times **lighter** than atmospheric air. It might be used for aërostatic purposes; but on account of the expense its preparation incurs, common coal gas is used in its stead to fill up balloons. *Gas* is 3 times lighter than air.

18. Oxygen (p. 244). — **Oxygen** keeps up **combustion**; in other words it is oxygen that makes our fires burn and our lamps to give light, etc.

19. It is **oxygen also that keeps up our very life**, and along with our life, that of all animals and plants.

20. Air (p. 246). — Air is a *mixture* of oxygen *and nitrogen* in the proportion of one fifth of oxygen to 4 fifths of nitrogen.

Pure nitrogen is obtained by causing phosphorus to absorb the oxygen of the air.

21. Nitrogen (p. 248). — Pure **nitrogen** is incapable of keeping up combustion; even life is extinguished by it.

22. Carbon (p. 252). — **Carbon**, combined with hydrogen and oxygen compose almost all vegetable matter.

23. Again it is with oxygen and hydrogen that carbon is united in all *animal fat* as well as in vegetable oil.

24. In the flesh and in the brain, the carbon is moreover accompanied by nitrogen.

25. *Animal black* is simply carbon obtained by the calcination of bones in closed vessels.

26. Thus, it is with *four simple bodies combined* (carbon, hydrogen, oxygen and nitrogen) that nearly all substances which form the bodies of animals are constituted.

27. The **coke** that remains when the gas has been extracted from the coal is almost pure carbon.

28. *Black-lead* or *graphite*, and **diamonds,** are also other forms of carbon.

29. Carbonic oxide (p. 255). — When charcoal, coal, or coke burn slowly, it unites with oxygen and forms a gas called *carbonic oxide.*

30. Carbonic oxide is a **very violent poison.** A thousandth part of this gas mingled with air suffices to kill rapidly.

31. In cooking ranges, heated with charcoal, and in stoves also, a great proportion of *carbonic oxide* is formed.

32. Thence the great importance of having chimneys that draw properly, and the great danger of going to sleep in a room heated by a portable stove.

33. **Carbonic acid** (p. 256). — When either coal or charcoal, or other combustible, burns briskly and well, it unites with the oxygen of the air and forms a gas which is called **carbonic acid**, which contains twice as much oxygen as the carbonic oxide.

34. Carbonic acid, although much less dangerous than carbonic oxide, can, notwithstanding, occasion very serious illness and even death.

35. Man, in the process of breathing, absorbs oxygen and gives back *carbonic acid.*

36. Carbonic acid is also formed in the fermentation of *beer*, and in that of *wine*. It is the presence of the carbonic acid that renders these fermentations so dangerous.

37. **Carbonate of lime** (p. 258). — The carbonate of lime is a combination of carbonic acid gas and lime.

38. *Chalk* is carbonate of lime.

39. **Oxides** (p. 260). — Lime is an *oxide of calcium,* that is to say, a combination of *oxygen* with the metal *calcium.*

40. Oxygen combines in like manner with all metals, thereby forming *oxides.*

41. Iron *rusts* in damp air; rust is a combination of iron with oxygen of the air: it is *oxide of iron.*

42. In damp air, copper is covered over with a greenish substance called **verdigris**. This also is a combination of copper with the oxygen of air, an *oxide of copper.*

43. Gold and silver *never* oxidise by mere exposure to air, and for this reason they are always found in the earth in a pure state, or as it is said in a *native* state.

44. Iron, zinc, tin, lead, on the contrary, are almost always combined either with oxygen or with sulphur.

45. **Lime** is an *oxide of calcium.*
Potash is an *oxide of potassium.*
Soda is an *oxide of sodium.*
Magnesia is an *oxide of magnesium.*

46. **Acids-Bases. — Salts** (p. 263). — *Carbonic* acid, *sulphuric* acid (vitriol), *phosphoric* acid, *nitric* acid, commonly called *aqua-fortis*, and in general all the compounds of oxygen with non-metallic bodies, are *acids*, as their names tell.

47. *Lime, potash, soda, and magnesia* are **bases**.

48. The combination of an acid and a base is called a **salt**. For instance, carbonate of lime (chalk) is a salt, composed of carbonic *acid* and oxide of calcium.

SUBJECTS FOR COMPOSITION.

1st **composition** (p. 238). — Mixtures and combinations.

2nd **composition** (p. 240). — Composition of water. — Analysis of water by electric current. — Synthesis of water (p. 245).

3rd **composition** (p. 242). — Hydrogen, combustible and explosive body. — Its weight relatively to that of air. — Fire-damp. — Gas that lights our cities.

4th **composition** (p. 244). — Oxygen. — The part it plays in combustion. — Its presence in water, in air.

5th **composition** (p. 246). — Air. — Its composition. — Nitrogen. — Preparation of nitrogen with phosphorus. — Properties of nitrogen (p. 249).

6th **composition** (p. 245-251). — Water is a chemical combination, air a mixture.

7th **composition** (p. 252). — Carbon. — Its presence in animal as well as in vegetable matter. — Divers forms of carbon.

8th **composition** (p. 254). — Production of the combustion of carbon. — Carbonic oxide. — Carbonic acid.

9th **composition** (p. 258-259). — Analysis of carbonate of lime. — Synthesis.

10th **composition** (p. 260). — Oxides. — Salts. — Acids.,

VI — ANIMAL PHYSIOLOGY.

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220. It is undoubtedly a very interesting thing to learn the names of animals, of plants, or stones, where and how they are found, how they resemble each.other or differ from one another, what use we can make of them or how we are to guard ourselves against them. It is very interesting to know how bodies fall by attraction, how light is reflected, how electricity is produced. But what is infinitely more interesting *still, is to know how we ourselves live*, and how it has been possible for us to observe or to produce so many marvellous things, and to learn the *history of the animals* that surround us, **1.** whose history is pretty nearly the same as our own. **Physiology** (from two Greek words *physis*, nature, and *logos*, study) is the name given to the science that treats of these vital phenomena

221. The three problems of physiology. — 1. *Nutrition* (fig. 1). Look at that brood of little chickens in the court-yard. Not one of them weighs much above 1/2 lb; yet in a few months they will be as big as their father or mother, and will weigh several pounds. After this they will remain about the same size and weight all their life long. Were I to ask how they are able to grow thus, where they find these pounds they thus add to their primitive weight, you would unhesitatingly answer that it is the result of the grain they eat, of the *nourishment* they consume!

Fig. 1. — In six months the little chickens will be as big as their father and mother : *nutrition*.

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1. What is physiology?

But do you think that in six months time, they have only eaten one or two pounds weight of food? Ah! the farmer's wife would tell you that you are greatly mistaken if you fancied this, and would speak of bushels instead of pounds. It is then but a *very insignificant part of their food* that remains in their bodies and is profitable to them. Moreover, even when they have reached their full growth, they continue to eat, *although their weight no longer increases.* What then becomes of the food they eat, and what use can it be to them?

1. This, my dear children, is the first problem that Physiology raises before us: *what becomes of food, of what use is it, and why do we take it?* for we are absolutely obliged to eat, under pain of death from hunger. **2.** This is the problem of **nutrition.**

222. 2. Sensation. 3. Motion. — Yet notwithstanding the importance of the problem of nutrition, it is neither the most curious, nor the most arduous of those presented to us by animal life.

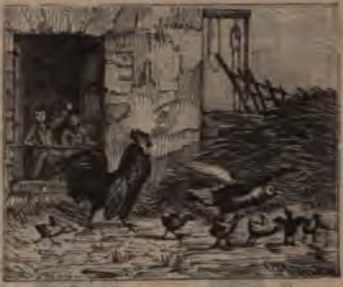

Fig. 2. — They are afraid : *sensation.* — See how they run : *movement.*

Paul, open the window suddenly and halloo at the chickens. *See how they run away* (fig. 2). They are frightened. Now let them get over their fright and throw them some crumbs of bread. *There they come running to pick it up,* quite delighted, the mother hen and all. What does this signify?

This shews in the first place that they *heard* the noise you made, that they *saw* your gestures; in a word they knew, they *felt,* that something or somebody was there. It farther shows that they *understood* that the noise and gestures were menacing in the first experiment, and favourable in the second. In short this

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1. What is the first problem we meet with in physiology? — 2. What name is given to it?

implies, that having understood, they moved, that is to say, *they gave orders to their feet and wings to move*, so as to enable them to avoid a danger that they believed to menace them, or to profit by an advantage they saw offered to them.

1. Here then are two other problems. **First** : *how are animals capable of feeling, understanding, willing?* this is the problem of **sensation** and of **intelligence**. 2. Then : *By what means are their orders obeyed?* How is it that the whole body, the feet and wings when there are any, obey the order, and execute the necessary movement? This is the problem of **motion**.

We have then before us three great problems. We will study them one after another. I will first speak to you about *motion*, because it will lead us to learn the history of the *bones* and the *skeleton*, that we must necessarily know in order to be able to study the two remaining problems.

I — MOTION.

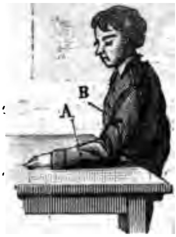

Fig. 3. — Put your fore-arm A flat on the table.

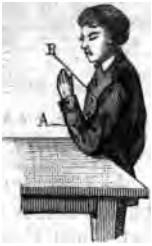

Fig. 4. — Fold the fore-arm A back upon the arm B.

225. The three factors of motion. — Come here beside the table and lay your fore arm A, flat upon it (fig. 3). Now fold your fore arm A backwards towards your arm B (fig. 4). Very well : this is a *movement*. Let us see what has taken place.

3. You are all perfectly aware that there is a *bone* B (fig. 5) in the arm and another *bone* C (in reality there are two) in the fore-arm. 4. These bones are in contact with each other at A, the

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1. What is the second problem in physiology? — 2. What is the third? — 3. What is the hard substance we *feel in our fore-arm?* — 4. What name is given to the point at which bones play on one another, for example, the elbow?

elbow, and there work upon one another. The movement you made had the result of bringing near each other the bone C and the bone B, just like the two arms of a compass. These bones play on one another at the elbow, a point disposed for that purpose, and which is called a *joint*, or to use a better expression an **articulation**.

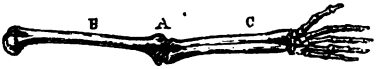

Fig. 5. — The bones C and B have played on each other at the articulation A of the elbow.

These bones are hard as wood. Were they all alone they would remain end on end, no more able to move than the arms of the compass. **1.** Something else is necessary to enable them to move, and this something is what is called a *muscle*.

Once more I ask you to bend your fore-arm back upon your arm. And whilst you do so, grasp with the other hand the thick part of your arm. During the movement you can feel at A something that grows harder and bulkier under your grasp. This is the great mobile muscle of the fore-arm, or to use the physiological expression the *flexor muscle* of the fore-arm, that is in action (fig. 6).

Fig. 6. — You feel something at A that is hard and bulky. — It is the *muscle* flector of the fore-arm.

2. There are then in this movement three parts to be considered : *bones*, *articulations* and *muscles*.

1. The bones, or the skeleton.

3. We already know that *skeleton* (fig. 7) is the name given to the bony framework of the whole body, and that this skeleton is composed of three great and distinct parts : the *vertebral column* with the ribs, B, the *skull* A, and the *bones* CC *of the limbs*.

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1. What name is given to that which causes the bones to move? — **2.** How many organs then have we to consider in each movement? — 3. What is a skeleton? **What** are the three leading parts **that** compose a skeleton?

\2.

224. Various shapes of bones. — 1. These bones are extremely varied in shape : look at these chicken bones that I laid aside at dinner yesterday (fig. 8) : some are long, A; others are flattened out, B; others short and irregularly shaped, C. Only, however different in form, all are of similar composition.

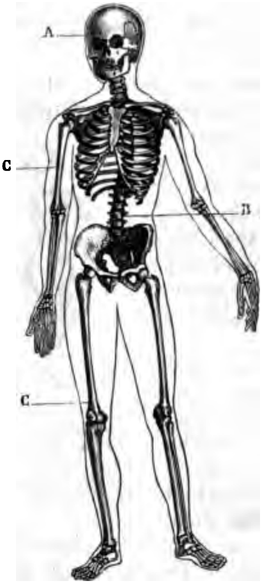

Fig. 7. — Human skeleton. A, skull. — B, vertebral column. C, bones of limbs.

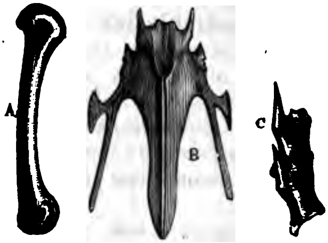

Fig. 8. — Chicken bones.

Fig. 9. — Bones contain carbonate of lime, phosphate of lime, and organic matter. — It is from bones that phosphorus is extracted.

225. Composition of bones. — See, I put one of these bones into strong vinegar (fig. 9). Immediately tiny bubbles of gas escape from it : this gas is carbonic acid. **2.** For *carbonate of lime* is one of the constituents of bones. They also contain *phosphate of lime; indeed it is, as I have already told you, from bones that phosphorus is extracted.*

See here is a bone similar to the one we have just spoken about, but which has remained steeped in vinegar

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1. Have all bones the same shape? — *2. Name the two* salts of lime contained in the bones. — What substance do we obtain from bones?

for several days. **1.** *The carbonate of lime and phosphate of lime* have both been dissolved, and that which remains of the bone is quite flexible. **2.** If I put it in the fire it will entirely disappear : this is what is called the *organic* part of the bone.

3. *It is the living part of bone.*

4. Thus there are two parts in bone, intimately related to each other : **organic** matter and **mineral** matter.

This last has not always existed in the bone. **5.** *When very young, bone contains no mineral matter:* it is at first quite **soft** and **flexible**; afterwards the earthy matter makes its appearance in certain parts. **6.** These soft flexible young bones are called gristle or **cartilage.**

226. Structure of bones. — Let us cut this rabbit's bone across, it is the thigh bone (fig. 10). **7.** You can see that it is *hollow* and encloses a sort of canal. **8.** In this canal is to be found a pulpy substance called **marrow.** **9.** *It is this substance that has the property of making bone,* and that enables it to become whole again when it has been broken or *fractured*, as doctors say.

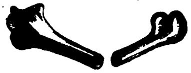

Fig. 10. — The bone is hollow and contains *bony marrow*, which has the property of making bone.

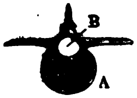

Fig. 11. — The vertebra of a rabbit, showing the spongy tissue A.

Here is a rabbit's vertebra* (fig. 11); I also cut it across. **10.** We do not find here a canal for marrow; but the bony marrow exists all the same, in this sort of *internal network* A which has some resemblance to a sponge, hence the name of *spongy tissue* given to it.

227. Vertebral column. — **11. The vertebral column** AB (fig. 12) is formed of a series of **vertebræ**, A,

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1. What remains when the carbonate and phosphate of lime are dissolved in vinegar? — **2.** What name is given to this matter? — **3.** What part of the bone is it? — **4.** In that case, what is there in bones? — **5.** What peculiarity do the bones of young animals present? — **6.** What name is given to bones that are soft? — **7.** Are bones solid or hollow? — **8.** What is in the internal cavity of bones? — **9.** What property does marrow possess? — **10.** Amongst vertebræ by what is the canal for marrow replaced? — **11.** Of what is the vertebral column formed?

piled the one on the other. **1.** Each vertebra (fig. 13) is composed of a solid mass or *body*, A, and a bony *ring*, B, behind. Pray observe I say « behind » because it is our own vertebral column I have in view; were I alluding to a quadruped I should say « above ».

2. All these rings placed one above another enclose what is called the *spinal canal.*

Several regions are observable in the vertebral column.

3. First the *neck*, or *cervical region* C, composed of *seven vertebræ* that have nothing particular about them. **4.** Then the thoracic or dorsal *region* D, composed in mankind of 12 vertebræ. **5.** Each of these bears a special bone or **rib** E directed forwards, in a curved manner, and united to the opposite rib by the *costal cartilage* F and a series of bones G that you can easily feel in front of the *chest.* **6.** The thoracic vertebræ, the ribs, along with the costal cartilages and sternum, form thus a sort of open work cage, wider in its under parts than in its upper, commonly called the *chest,* and scientifically **thorax** (a Greek word that has the same meaning).

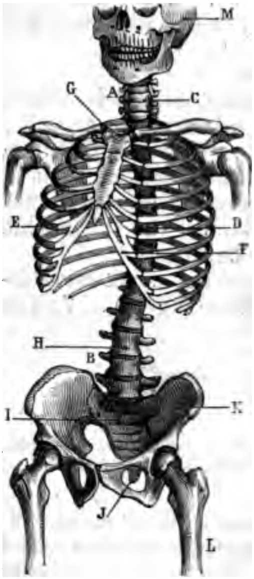

Fig. 12. — AB, vertebral column, containing the spinal canal behind.
E, ribs. — F, costal cartilages. — G, sternum. — I, sacral region. — J, the caudal region.
K, bones of the pelvis (hip).
L, thigh bone (femur).
C, cervical region.
D, thoracic »
H, lumbar »
I, sacral »

7. Next the dorsal region comes the *lumbar region,* H,

---

1. Of what is each vertebra composed? — **2.** What do all these rings, placed one on another, form? — **3.** What name is given to the region of the neck? — Of how many vertebræ is it composed? — **4.** What name is *given to the region* of the back? — *Of how* many vertebræ is it composed? — **5.** What important peculiarity do the vertebræ in the dorsal region present? In what manner is each rib united to the opposite one? — **6.** What do the dorsal vertebræ, the ribs, the costal cartilages and the sternum form? — **7.** What region comes after the dorsal one?

with ribless vertebræ like those of the neck C, **1.** then the *sacral region* I, in which five vertebræ are welded together so as to form only one bone, the **sacrum**, with which the bones K of the lower limbs articulate.

2. Lastly, there is the *caudal region* J, which in long tailed animals has often a great number of vertebræ, but in mankind is reduced to two or three little bones called *coccyx*.

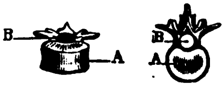

Fig. 13.

Vertebra seen from the front. Vertebra seen from above.

A, *body* of the vertebra.
B, ring or arch forming with those of the other vertebræ the spinal *canal*, in which is found the *spinal cord*.

228. Skull. — **3.** At the upper end of the vertebral column is situated the **skull** (fig. 14). It is a sort of bony box, the cavity* of which is continuous with that of the spinal canal (see p. 310).

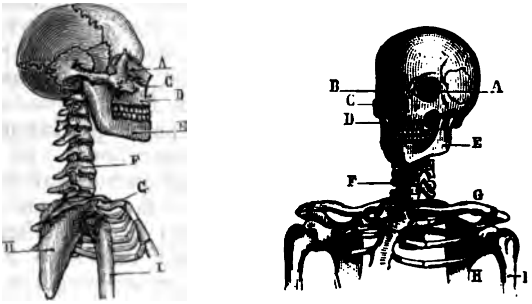

Fig. 14. — The skull.

A, B, orbits of the eyes.
C, nasal chambers.
D, upper jaw fixed.
E, lower jaw movable.
F, vertebræ of neck.
G, clavicle (collar bone).
H, scapula (shoulder-blade).
I, humerus (arm bone).

The skull is composed of a goodly number of bones whose names we will hereafter learn. **4.** In front are the cavities or **orbits** A B in which the eyes are set; C, the **nasal chambers**, and the two **jaws** D E, set with teeth, between which is the opening of the *mouth*.

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1. What name is given to the five vertebræ welded together, in the sacral region? — What bones does the sacrum support? — 2. What name is given to the three little bones in the caudal region? — 3. What is placed at the upper end of the vertebral column? — 4. What are the cavities in front of the skull?

1. The *upper jaw* D is stationary, being quite one with the skull. **2.** On the contrary the ***under jaw*** E is movable*, articulating with the skull as you all know.

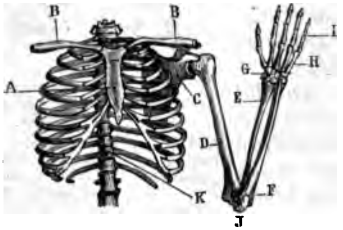

Fig. 15. — Upper limb (arm and fore-arm).

A, sternum (front of the chest).
B, clavicle.
C, scapula.
D, humerus (arm).
E, radius } Fore-arm.
F, ulna }
G, carpus (wrist bone).
H, metacarpus (palm).
I, phalanges (finger bones).
J, elbow (extremity of the ulna).

229. Limb bones. — **3.** *The upper limbs* (fig. 15) (*fore limbs* in quadrupeds*) are composed of several parts, as you know: the *arm* (from the shoulder to the elbow) *fore-arm, wrist, palm* and *fingers*. **4.** The names given to the bones are, **humerus**, for that of the arm D; **radius** and ulna or **cubitus** for the bones E, F, of the fore-arm; **carpus** for the wrist bones G; **metacarpus** for the bones H, of the palm; **phalanges** I, the finger bones. In reality, the metacarpal bones (those of the palm) are simply the first phalanges, the only difference being that they are not free like the others; but in this bat's wing you can see they are quite similar to the others, so that each finger seems to have four phalanges A, B, C, D (fig. 16).

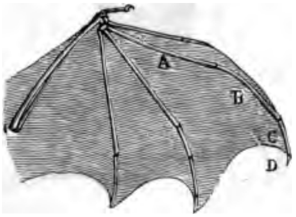

Fig. 16. — Extremity of a bat's wing showing the four phalanx of the fingers A, B, C, D.

5. One of the two bones of the fore arm, the *cubitus* or ulna F is the direct continuation of the humerus D, its upper end J forms the *elbow*, hence its name *cubitus*, a Latin word meaning *elbow*. It so fits the hume-

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1. Is the upper jaw fixed or movable? — **2.** And the under jaw? — **3.** What names are given to the *different parts of the* upper limbs? — **4.** *What name* is given to the bone in the arm? To the two bones in the fore-arm? To the wrist bones? To the bones in the palm of the hand? — To the finger bones? — **5.** What does the upper end of the humerus form?

rus D as to execute only compass-like movements.

1. The other bone, E *radius* (ray) turns on the cubitus in the most curious manner, carrying along with it the wrist, and the whole of the hand. These movements of the radius render us most important services : no animal is so well endowed in this respect.

2. The arm is attached to the body by two bones : the **shoulder blade** (see preceding page) a flat bone, with which the *humerus* D is articulated. The shoulder blade is directed backwards and lies upon the thorax, without being united with it anywhere; the **clavicle**, B, or **collar bone** is placed like a cross bar, passing between the shoulder blade and the sternum, A, where it is firmly fixed.

3. In the *lower limb* (fig. 17) we distinguish the *thigh*, the *leg* (from the knee to the foot) the *instep*, the *sole*, the *toes*.

4. The names of the bones are : **femur** C, the thigh bone; **tibia** and **fibula** the two bones E, E′ of the leg; **tarsus**, the bones F, G of the instep, **metatarsus** the bones H of the sole; **phalanges** the bones I of the toes. The *tibia* is the thick bone of the front of the leg, shin bone as it is called : it supports the body, and extends from the *femur* C to the *tarsus* F; the fibula is a long slender bone, it has no special use.

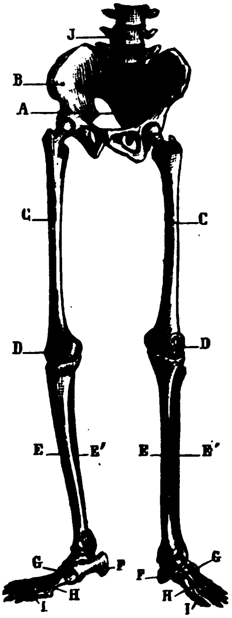

Fig. 17. — Lower limb (thigh, leg and foot).

A, sacrum (inferior extremity of the vertebral column).
B, pelvis (hip).
C, femur (thigh).
D, patella (knee-cap).
E, tibia } Leg).
E′, fibula }
F, G, tarsus (instep).
H, metatarsus (sole).
I, phalanges (toes).
J, vertebræ (lumbars).

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1. What peculiarity does the radius present? — 2. By what bones is the arm attached to the body? — 3. What do we remark in the lower limb? — 4. What name is given to the thigh bone? To the two bones in the leg? To the bones in the instep? To the bones in the soles of the feet? To the bones in the toes?

1. The two femora C, that of the right thigh and that of the left, articulate upon a broad and solid bony girdle, B, called the **pelvis**, A, (the haunch), which is joined backwards to the sacrum (the *under* end of the vertebral column). This forms a solid base upon which the body can rest.

So much for the bones; we will now pass on to the study of their articulations.

2. Articulations.

230. 2. Articulations *are*, as I have already told you, *the parts* D (fig. 18) *where any two or more bones, that are to play on one another, come in contact.*

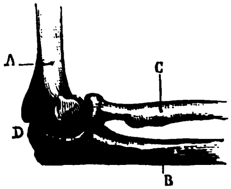

Fig. 18. — D, articulation. — A, humerus. — B, ulna. — C, radius.

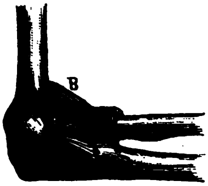

Fig. 19. — B, ligaments holding the bones in place.

3. In order to facilitate their movements each of the bones is in those parts covered over with a sort of polished shiny cap of gristle, constantly kept moist by some drops of liquid. **4.** And in order to assure sufficient solidity to the articulation, fibrous bands or **ligaments** (fig. 19) pass from one bone to another.

5. When, subsequently to a stumble or any awkward movement these ligaments are strained, sometimes even rent, people say that the member is **sprained**. **6.** When the movement has been so violent that the two bones are rent apart, the articulation thus being destroyed, the limb is said to be *dislocated*, and it is very impor-

---

1. Upon what do the two femora articulate? To what bone is the *pelvis* or basin joined? — 2. Give the definition of an articulation. — 3. What facilitates the movements of the joints? — 4. How is the solidity of the articulation assured! — 5. What is a sprain? — 6. Whe is there a dislocation?

tant that it should be set in its proper place without delay.

You can easily understand that articulations may be very differently shaped according to their destined functions. But these are details into which we cannot enter at present.

3. Muscles.

231. It is much more interesting for us to go on studying **muscles**, which play an active and efficacious part in locomotion.

1. What physiologists* call *muscles* is what is commonly called *flesh* or more vulgarly *meat*. **2**. You can easily see that it consists of a mass of red filaments C (fig. 20) placed alongside of each other and fastened to a bone at each end.

3. Often the muscle is not itself fixed on the bone, but is attached to it by sorts of strong whitish cords A, A, called by anatomists* **tendons** or **sinews**. The muscle in this case acts by the intermediary of the sinew, as you might draw anything, not directly with your hands, but with the help of a rope.

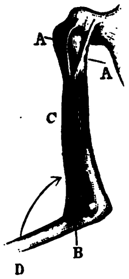

Fig. 20. — C, one of the muscles of the arm. A, A, tendons. When the muscle C, contracts, the fore-arm D, is raised.

232. Musculary contractility. — The filaments or fibres of muscles have a very peculiar property. **4**. When they are pricked, or cut, or burned or struck, when they are excited by electricity, in a word, whenever and however they are irritated, they *shorten*, or to use a more technical expression, they **contract** as physiologists say. **5**. Evidently this brings their two ends nearer to each other, and along with them, the bone to which they are fastened.

This is what happened to your fore arm a little while ago.

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1. By what name are muscles usually known? — **2**. Give a definition of a muscle. — **3**. How are the muscles attached to the bone? — **4**. What peculiarity do they present? — **5**. What are the consequences of this contraction?

1. In your arm there is a muscle that passes from the upper part, A, of the humerus to the beginning of the B, *fore-arm*. When it shortens, as the humerus is solidly fixed to the shoulder, the result is, that the fore-arm is lifted up in the direction of the arrow, carrying the hand along with it. Of course the muscle cannot become shorter without becoming thicker, and that is why you felt it become hard and bulky in your arm.

A very curious thing it is to study closely, this *contraction* of the muscles. Luckily the farmer's wife has brought for supper a rabbit that was killed but a few minutes ago. Paul, fetch me the electric pile. **2.** I touch the two ends of the muscle A with the two poles (fig. 21), see how it immediately swells out and *shortens*, and yet the rabbit is quite dead.

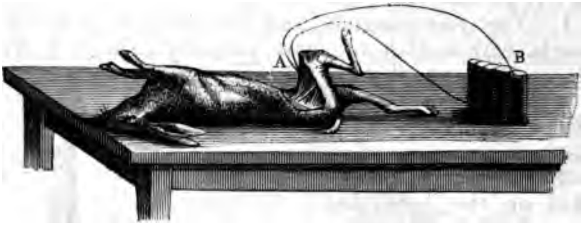

Fig. 21. — I touch the two ends of the muscle A with the two poles of the pile. B : the muscle *contracts!*

233. Number and variety of muscles. — All other muscles give a similar result, and you see I provoke all sorts of movements by exciting successively the different muscles of the dead rabbit.

And these are not few in number. Some set the feet in motion, bend or spread out the toes; others act on the position of the head, others on the vertebral column, others on the abdomen. In short, to give you some idea of their multiplicity, I may tell you that upwards of two hundred have been counted in a man's body, each having its own special part to play.

You must understand, however, that it is not my intention that we should study all these muscles; that is for doctors and surgeons * to do, for they must needs be

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1. *Show the effect of muscular contraction in your fore-arm.* — 2. How can a muscle be made to contract by artificial means?

well versed in *anatomy*, that is to say, the details of all the parts of the body.

234. **Death stiffening.** — See the muscles of the rabbit hardly contract any longer : In a few minutes it will even be quite impossible to excite any one of them ; they will be quite stiff; **1.** this is what is called the **death stiffening**. This inevitably happens to all dead animals. **2.** When it ceases, the muscle is ready to rot, or properly speaking to *putrefy;* people say *putrefaction sets in.*

Locomotion.

235. There are many kinds of movements, all of which are executed with the aid of the *muscles :* for instance, we can at will bow down, lift up, or turn about our head, carry our hands to our mouth or put them behind our back; open or shut our jaws, our lips, our eyes, etc., etc.

But there are some movements of peculiar interest because they enable us to move from place to place, to walk, to run, etc. **3.** These are said to be movements **of locomotion** (from the Latin *lòcus*, place, and *movere,* to move). It is to such movements I now wish to direct your attention.

236. Standing. — **4.** In the first place, I must tell you about the muscular action required to **stand upright.**

I seem rather to astonish Master George. — Why, yes, Sir, you speak about movement: when a person stands he makes no movement, for he does not stir from the spot. — What you say looks true enough certainly, and yet it is not so; for if the person makes no evident movements, at least he hinders certain movements being made. See, stand forward before me. Do you think you could remain so for a long time. — Oh no, sir! one is soon tired of standing motionless. — Why should one soon be tired? — Because one must keep

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1. What phenomenon may be observed in all dead animals? — 2. When the rigidity ceases, into what state will the muscle shortly enter? — 3. What name is given to the movements that enable us to walk? — 4. What name is given to the muscular actions that enable us to stand upright?

perfectly upright. — And how do you keep yourself quite upright? In stretching your legs, your back, and your body, is it not? What would happen were you not to stretch yourself up? — My legs would bend, and I should fall down.

—Well, of course that would be the result, and certainly this downfall would be a movement, though an unpleasant one that you would rather avoid. How do you avoid it? **1.** *By contracting certain muscles.* Follow attentively what I am going to tell you.

See here, your foot rests firmly on the ground. **2.** If you did not keep your muscles tight, your *leg*, from D to B would bend forwards. To, keep it from doing so, the muscles A of the calf of the leg (fig. 22), which reach from the tibia (shinbone) to the heel, contract vigorously. Put your hand on them, and you can feel that they are hard. Thus you see the leg is fixed straight above the foot. **3.** Again were you to let your muscles slacken, the *thigh* from D to C would bend backwards. To keep you upright, a powerful muscle C, situated in front of the thigh, contracts and straightens it. This muscle presents a curious peculiarity. **4.** At its lower end it is terminated by a thick *sinew;* this is

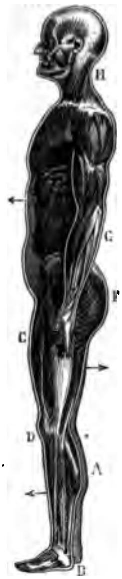

Fig. 22. — The upright position is not a state of repose, far from it: that can only be obtained by *contracting* certain muscles.

A, muscle of the calf which prevents the leg (from the knee to the foot) from falling in front.
C, muscle which prevent the thigh from bending backwards.
F, muscles which prevent the body from falling forward.
G, muscles of the loins which sustain the vertebral column.
H, muscles of the neck that support the head.

---

1. How do you keep yourself upright? — 2. Which muscles prevent the leg, from the knee to the *foot, from bending* forward?— 3. What muscle prevents the thigh from bending backwards?—4. What peculiarity does this muscle present?

in itself nothing beyond that which we have already seen, but what is very remarkable is, that in the middle of the sinew a bone exists, the patella or **knee pan**, that presses, when the muscle is in action, upon the femur (thigh bone), and on the tibia (shinbone), and which closes the front of the knee joint : with your fingers you can easily force this patella to move.

So much for the leg and the thigh. **1.** But the *body* also would fall forwards were it not kept up by the large muscles that are fastened behind to the pelvis (the haunches). **2.** Lastly, the *vertebral column* and the *head* are also kept up and sustained in erect attitude by the contraction of the muscles of the loins G and the neck H.

3. *So you see your body is by no means at rest when standing upright, far from it.*

4. It is for this reason that the calves of the legs, the thighs, the loins and the neck are soon pained under prolonged standing. Even when seated, neither your vertebral column nor your head is at rest. And that is why backs were invented for chairs; for that reason also you let your bodies lie forward on your desks, although you are told that this is a very bad habit, and that you may become hump-backed if you do not take care.

237. Walking and running. — From *standing* to *locomotion* the transition is easy. George, you that have remained on foot, lean forward; more so, and yet more so... Ah, you were just going to fall, so you put forward your left foot : in doing this you made a *step.* There you are now in equilibrium on your two feet set apart. Lean forward once more; again you feel ready to fall, and this time it is the right foot you pass rapidly in front of the left. You have thus taken another step, you have **walked.** **5.** *Walking is then a series of partial falls in a forward direction : falls checked just in time.*

In walking, at least one foot is always on the ground, the body being supported alternately by the one and the other. In *running*, the feet are in such rapid motion

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1. Which muscle prevents the body from falling forward? — 2. Which are the muscles that sustain the vertebral column and the head? — 3. What conclusion do you arrive at in consequence? — 4. What are the results of standing a long time? — 5. What is walking?

that they are never both at a time on the ground; and at regular intervals the body is altogether in the air, and not in contact with the soil at all. 1. So *running is a series of leaps.*

There is great variety in the detail of locomotion of animals.

2. Quadrupeds *walk*, *trot*, *gallop*, etc.; aërial* animals *fly*; aquatic* animals *swim*; limbless animals *creep*. 3. But however varied these movements may outwardly be, they are always *the result of muscles contracting and acting upon solid parts.* 4. In the case of vertebrates*, the solid parts are the bones; in the case of invertebrates*, the muscles act upon the hardened skin, as with insects for example: be this as it may, the *muscle* always plays the most important part.

238. Voluntary and involuntary motion. — All the movements of which we have just been speaking are **voluntary**. 5. You can lift your arm or keep it still, open or close your mouth at will. *Yet there are movements that you can make at will, but which your will cannot prevent.* 6. Thus you can wink as often as you like; but I defy you to keep from winking were I to touch your eye, or even were I to make you believe I wished to touch it: you can also accelerate your breathing, but you cannot avoid breathing. Put a bit of bread in your mouth and chew it; as long as it is in your mouth you can do with it what you will, but once it enters into your throat it is seized, carried off and swallowed without your having any more power over it. We have then before us a second category of movements that are to a certain extent both *voluntary* and *involuntary*.

There also exist others, quite **involuntary**, *which we can neither produce nor hinder, and of which we often have no knowledge.* 7. For instance, unless we put our hand on our breast *we do not feel our heart beat; we have not the sensation* that our stomach and

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1. What is running? — 2. Name the different varieties of locomotion in animals. — 3. In a general manner how are these movements produced? — 4. By what are the bones *ordinarily replaced* amongst the invertebrates? — 5. Name some voluntary movements. — 6. Mention some movements that can be produced at will, but that cannot be prevented. — 7. Name some others that are quite involuntary.

our intestines contract, and *we might vainly endeavour* to accelerate the beating of our heart or the contraction of our stomach.

These movements over which we have no control, are the most important for the conservation of our existence. Were we able to arrest the beating of our heart or our respiratory movements, we should immediately perish: it is therefore better for us that we have no power over them.

SUMMARY. — MOTION.

1. The three problems of physiology are **Nutrition**, **Sensation**, and **Motion**.

2. **Motion** (p. 272). — In every movement there are to be considered : the *bones*, the *joints*, and the *muscles*.

3. **Bones** (p. 273). — The skeleton is composed of three distinct parts : the *spinal column, and ribs, the skull*, and the *bones of the limbs*.

4. The bones are composed of an organic or animal substance called *cartilage*, and of a stony-mineral matter formed of *carbonate of lime* and of *phosphate of lime*.

5. The *marrow*, which has the property of making bone, is found in the interior of the bone itself.

6. **The spinal column** (p. 275). — The spinal column is composed of *vertebræ*, which vertebræ are themselves formed of a solid *body* and a *ring* or arch.

7. The superposed rings of all the vertebræ form a sort of tube, called the *spinal canal*, which canal communicates with the cavity of the skull.

8. The dorsal or thoracic vertebræ bear *ribs*, united in front by the *costal cartilages*, and the *sternum*. The kind of cage thus formed is the *thorax*.

9. At the lower part of the spinal column, five vertebræ, closely united, form one single bone, the *sacrum*, which is attached to the bone of the *pelvis* (haunch).

10. **The skull** (p. 277). — The **skull** is placed at the upper extremity of the spinal column.

11. In the skull you can observe the *orbits* for the two eyes, the cavities of the *nasal chambers*, and, underneath, the two *jaws* bearing teeth.

12. The upper jaw, intimately united with the skull, is *fixed*; the under jaw moves up and down.

13. **Bones of the limbs** (p. 278). — The bones of the upper limbs are : the *humerus*, which passes from the shoulder to the elbow; the *radius* and the *ulna*, from the elbow to the wrist; the *carpus*, which comprises the wrist bones; the *metacarpus*, which

comprises those of the palm of the hand; and the *phalanges* or bones of the fingers.

14. The elbow is formed by the extremity of the ulna.

15. The humerus (arm-bone) articulates upon the scapula or shoulder blade, which is lodged behind *upon* the thorax, but without however fixing itself to the spinal column.

The scapula is supported by the *clavicle* (collar-bone), which extends from it to the *sternum* (breast-bone), to which it is solidly fixed.

16. The bones of the lower members are: the *femur*, which extends from the haunch to the knee; the *tibia* and the *fibula*, which extend from the knee to the ankle; the *tarsus*, which comprises the ankle bones; the *metatarsus*, which comprises the bones of the sole of the foot; and the *phalanges* or bones of the toes.

17. Besides all these there is still another bone at the knee called *patella*.

18. The two femora articulate with the *pelvis* (haunch bone) which extends to, and joins the *sacrum* (lower extremity of the spinal column).

19. **Joints** (p. 280). — **Joints or articulations** are those points at which two bones, destined to play on each other, come in contact.

20. To assure the solidity of the joints, there are bandlets or *ligaments* which go from one joint to another.

21. A *sprain* is occasioned by the distending or rending of these ligaments; when any two bones are forcibly disconnected a dislocation is the result.

22. **Muscles** (p. 281). — **Muscles**, vulgarly called *flesh* or *meat*, are masses of red filaments or fibres fixed to the extremities of the bones, and having the property of *contracting* or shrinking.

Instead of being fixed directly on the bones themselves, they are attached to them by means of *tendons* or *sinews*, a sort of cord, white and firm.

23. It is our muscles which permit us to move our arms, legs, head, jaws, lips, cheeks, eyes, etc.

24. When we *stand* upright, it is the *contraction* of muscles that prevent the body from bending. To stand, then, is not to rest.

25. To lift your arm, to open your mouth, etc. are *voluntary* movements; but there are movements which are to a certain extent both *voluntary* and *involuntary*, such as winking, for example; others again are always *involuntary*, such as the beating of the heart, or the contracting of the stomach.

[Simple *Subjects for composition* are to be found at page 323.]

II — NUTRITION.

239. How, and why do we eat? We are all aware *that we take* food, that we *digest* it, that we *absorb* the greater part and that we eliminate the rest. But how does all this work go on, and what is the use of it?

1. Digestion.

240. We procure food, we put it in our mouth; when this food is of little bulk, or when it is liquid, we swallow it immediately; when it is *too* big for this we chew or masticate it, in order to break it up.

241. Teeth. — 1. The process of *mastication** is gone through with the help of the **teeth,** that cut and masticate, and the **tongue**, a muscular organ, very active and easily moved, that constantly brings the food under the teeth, and rolls it into a sort of ball when ready to be swallowed.

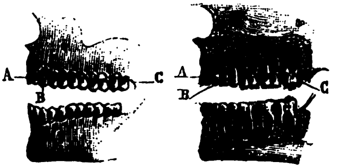

Fig. 23. — Human jaw, showing the teeth covered and uncovered by the gums. — A, incisors. — B, canines. — C, molars.

2. There is great variety in the shape of *teeth* (fig. 23): they are sharp in front, *incisor* teeth A; pointed on the sides, *canine* teeth B; grinders behind, *molar* teeth C. **3.** I have, or rather I ought to have, in my mouth in each jaw, 4 incisors, 2 canines, 10 molars, altogether 32 teeth. **4.** You children when under seven had only 20 in all, having but 4 molars in each jaw. Subsequently you lost those, and your *second dentition* began.

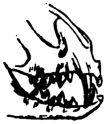
Fig. 24. — A cat's jaw.

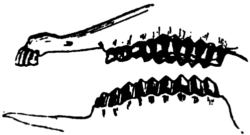
Fig. 25. — A sheep's jaw.

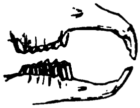
Fig. 26. — A rabbit's jaw.

The number as well as the shape of teeth varies greatly

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1. How is mastication performed? — 2. What are the different kinds of teeth? — 3. How many incisors has an adult man in each jaw? — How many canine? How many molars? — 4. How many teeth have we up to the age of seven? — Whence comes this difference?

13

according to the group of animals to which they belong. We have already seen that those of the cat (fig. 24) differ from those of the sheep (fig. 25) and those of the rabbit (fig. 26). But they all have essentially the same composition. **1**. They are all in ivory, and planted by one or several *roots* B B′ (fig. 27) into pits or *alveola* of the jaw. **2**. The part A that protrudes from the jaw bone is covered over with *enamel*, a transparent substance harder than the ivory. **3**. Inside the tooth is a cavity into which run tiny *blood vessels* and *nerves*.

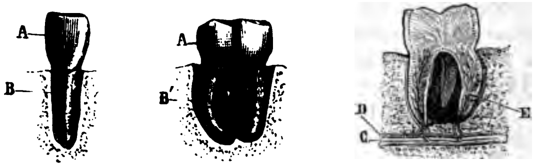

Fig. 27. — Teeth of man.

A, crown of the tooth covered with ivory.
B, root or fang of the tooth, implanted in the socket of the jaw.
C, veins } Blood vessels.
D, arteries }
E, clusters of nerves.

4. When it happens that the enamel is destroyed, the ivory decays and spoils very easily, a hole is formed and the tooth decays. If the hole reaches the cavity in which the nerves are lodged, it gives rise to acute pain, as almost everybody unfortunately knows from experience.

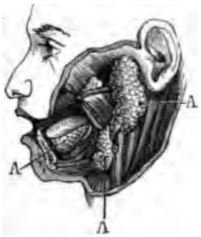

Fig. 28. — A, salivary glands.

242. Saliva. — **5**. The mastication of the food is facilitated by an outflow of *saliva*, a fluid formed in the **salivary glands** A (fig. 28).

6. The name *gland* is given in physiology to organs

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1. Of what material are teeth formed? How are they placed? — 2. With what material is that part of the teeth covered that is exposed? — 3. What is found in the cavity of the tooth? — 4. From what cause is the decay in teeth produced? When is there a painful sensation? — 5. By what liquid is mastication facilitated? — 6. To what organs is the name of gland given in physiology? Name some of the glands.

that *secrete*, that is to say that fabricate and give out particular liquids or products: thus tears are formed in the *lachrymal glands*, sweat in the *sudoriparous glands*. **1**. The saliva runs into the mouth by several small openings, some of which are under the tongue, near its root, and are very easily seen.

243. Deglutition. — **2**. When the aliments have been properly masticated and mixed with saliva, the tongue guides them to the opening of the throat, where by a muscular contraction they are seized and swallowed. This operation is called *deglutition*.

244. Alimentary canal. — **3**. The aliments then descend a sort of tube A (fig. 29) called **œsophagus**, situated in front of the vertebral column, therein they traverse the whole breast and arrive at the **stomach** C. **4**. This tube is of course very long in long-necked animals, and it is quite easy to see the food passing down in the neck of a horse or a goose.

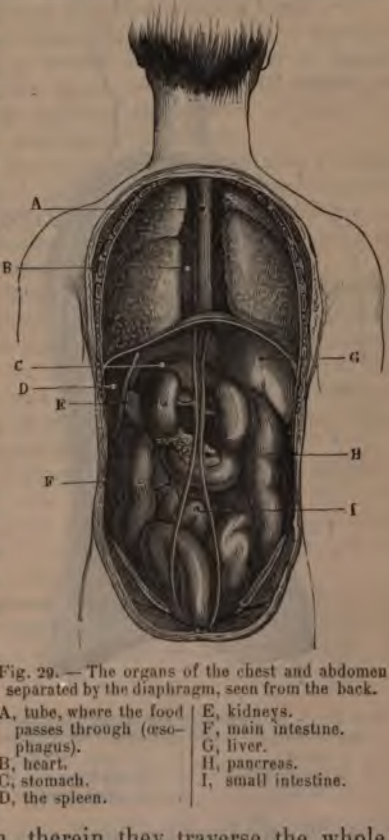

Fig. 29. — The organs of the chest and abdomen separated by the diaphragm, seen from the back.

A, tube, where the food passes through (œsophagus).
B, heart.
C, stomach.
D, the spleen.
E, kidneys.
F, main intestine.
G, liver.
H, pancreas.
I, small intestine.

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1. How does the saliva enter the mouth? — 2. What is deglutition? — 3. What becomes of the aliments as soon as swallowed? — 4. What is to be observed in the alimentation of animals with long necks?

1. The stomach is a sort of pouch (fig. 30) capable, in man, of holding about from two to three pints. **2.** From it the food passes into the **small intestine**, another tube about the thickness of one's thumb and coiled on itself a great number of times, this leads into the **large intestine** F which carries off and expels the useless residue.

3. These intestinal canals are girded with muscular fibres, which by their contractions, force the aliments to make their way from one end of the *alimentary canal* to the other, that is from the mouth to the large intestine.

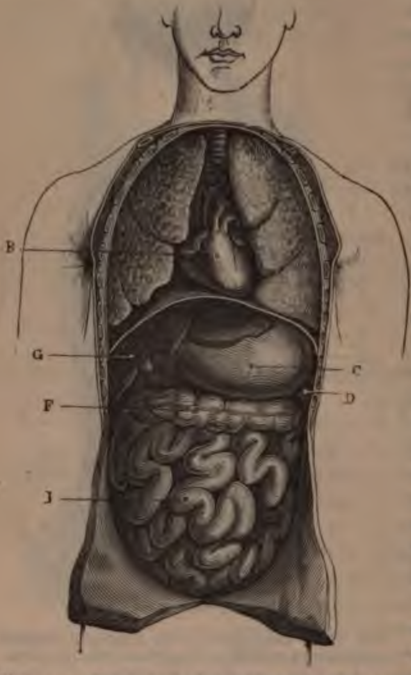

Fig. 30. — The organs of the thorax and abdomen, separated by the diaphragm, seen from the front.

B, heart.
C, stomach.
D, spleen.
F, large intestine.
G, liver.
I, small intestine.

245. Digestive juices. — But this is neither what is most curious nor most important in the digestive operation.

4. The food not only makes its way through the alimentary canal, but it is also **transformed** therein *under the influence of liquids or* **juices**, *infused into it by different glands.*

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1. About what is the capacity of a *man's* stomach? — **2.** Where do the *aliments enter* on leaving the *stomach?* — **3.** Is the digestive tube composed of inert tubes? — **4.** Do the aliments only pass through the digestive tube?

1. The first of these juices is the *saliva*. If any of you have ever happened to chew and rechew for a good while a little bit of bread, you may have observed that after some time the bread acquired a sweet taste.

2. And this is not astonishing, since saliva has the effect of *transforming bread into* **sugar**, or to speak with more precision the *flour or starch into sugar;* it is of no consequence whether this starch or flour be made from wheat or potatoes or peas, etc.

3. The coat of the stomach is beset with minute glands, from which ooze out, drop by drop, a considerable quantity of juice called **gastric juice** (from *gaster*, stomach). **4.** *Gastric juice dissolves meat, white of egg, and in general all animal matter.*

5. Besides, the walls of the small intestine are all beset with small glands from which oozes a juice capable both of transforming into sugar all floury or starchy matter, and dissolving all the meats which have escaped the action of the saliva and the gastric juice. **6.** Another gland almost as big as my fist, known under the name of **pancreas**, acts upon meat, floury, fat matter.

7. There is also an immense gland called the **liver** G, lodged at the right side of the abdomen near the stomach. This secretes and pours into the small intestine, the greenish yellow bile; in doing that it also effects important changes in the blood itself.

246. The purpose of digestion. — **8.** In short you see that the *purpose of digestion is to* **dissolve** *the aliments*, and so act upon them as to render them fit for use.

2. Absorption.

247. Blood the dispenser of food. — But why all these processes. **9.** It is because, *our food in order to be able to feed and nourish us, must needs* **pass through the coats** *of the intestine and enter into the*

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1. Name one of the digestives juices. — 2. What is the effect of saliva? — 3. Name juice secreted by the stomach. — 4. What is the effect of gastric juice? — 5. What is the office of the glands that are found all along the small intestine? — 6. Amongst these glands, name one that is nearly as large as the fist. — 7. What is the function of the *liver*? 8. What is, in short, the purpose of digestion? — 9. Why all these processes?

blood. Of course if the aliments remained in a solid state this would be impossible.

1. If the aliment remained in the alimentary canal alone, it would be of no use to the body, one might almost as well have it in the hollow of their hand. *For the skin that covers over all our body, enters from the lips and lines the whole alimentary canal.*

2. Only it loses the appearance it has outside the body and becomes more pulpy: in this state it is called a **mucous** membrane.

3. The dissolved aliment must **pass into the blood,** and be carried by it to the utmost parts of the body. For, as you well know, there is blood everywhere in your body: you may prick yourselves no matter where, with the finest of needles, a drop of blood will always be forthcoming.

3. Blood and Circulation.

248. Blood. — Were I to ask, what is blood? You would all answer: it is a red liquid. And indeed it looks so. **4.** Only in reality, *blood is a yellowish liquid in which float a countless number of tiny red bodies* called *corpuscles.* In a cubic line there are about 50 millions of those little bodies (fig. 31). Little

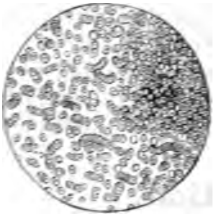

Fig. 31. — A. drop of blood, and its corpuscles (as seen with a microscope).

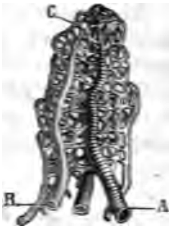

Fig. 32. — Ramification of a blood vessel seen under a microscope. A, artery. — B, vein. — C, capillary vessels.

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1. Does the aliment produce any useful effect as long as it remains in the digestive tube? — 2. What name *is given to* the skin that lines the interior of the mouth? — 3. In what condition does the aliment serve to nourish us? — 4. What is blood.

though they be, they are so very numerous that it is computed that were all the corpuscules contained in the blood of one man (about a gallon and a quarter) to be laid in a single row close end to end, they would form a chain long enough to go 4 times round the globe.

249. Coagulation of blood. — When blood is drawn from a blood vessel and set in contact with the air, it coagulates, that is to say, it curdles into a jelly-like mass.

After a short time the relatively solid part thickens and shrivels up until it becomes a sort of dark red clot, which floats in a yellowish liquid called *serum*.

This curious property of blood is of very great importance indeed; were it otherwise, the least cut or wound would bleed until complete exhaustion took place, whereas coagulation stopping up the opening of the vessel, hinders the outflow and allows the blood to retake its regular course.

250. Circulation of the blood. — Blood is contained in fine tubes or vessels, disposed in a complicated network all through the body. **1.** In the breast, a little to the left, is the *heart* B (p. 292), a sort of pouch, or rather a sort of *hollow muscle*, that contracts with regularity, expelling the blood it contains.

2. The blood is brought to it by *veins*, and is carried out by *arteries*. The arteries break up into smaller and smaller branches as they approach their destination (fig. 32). **3.** They terminate in very fine tubes called **capillary vessels**, thus named from the Latin word *capillus*, hair, although they are much finer than the finest hair. **4.** *These capillary vessels put the arteries in communication with the veins* (fig. 33), thus permitting what is called the **circulation of the blood.** The veins, unlike the arteries, carry the blood back to the heart, and unite to form larger and larger trunks as they approach that organ. **5.** The blood flows with great rapidity from the heart through the arteries into the capillaries, thence into the smaller veins, then into

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1. What is the function of the heart? — **2.** How is the blood taken to the heart? — By what is it carried out of the heart? — **3.** How do the veins and arteries terminate? — **4.** What have the capillary vessels to do? — **5.** What course does the blood take in going through the body? — How long a time does it take?

the larger veins, that bring it back to the heart : all this course is gone through in half a minute.

1. The walls of **veins** are thin and flaccid, so that when opened, as in *bleeding*, they have a tendency to fall together, thus causing the opening to close; therefore, unless the wounds bear upon the large veins of the thigh, or those of the armpit or the neck, but little danger is incurred.

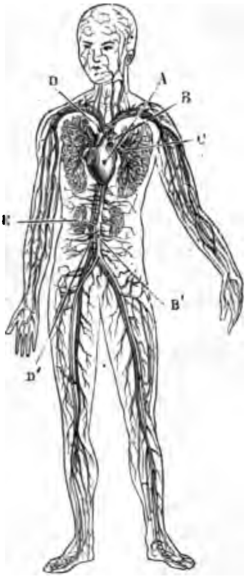

Fig. 33. — Circulation of blood.
A, heart.
B', trunk of the aorta.
B, origin of the aorta.
C, pulmonary artery.
D, posterior vena cava.
D', anterior vena cava.
E, veins and arteries of the kidneys.

2. On the contrary, **arteries** are *rigid and tube-like*, and when one is accidentally cut, the blood bursts forth with such force that it sometimes springs 3 yards off, hence *hemorrhages* (from the Greek *haima*, blood, and ***rhago***, to burst), which would soon prove fatal if the open artery were not bound up in time.

3. This property of arteries allows the blood under the impulsion of the heart (generally once every second) to produce the *shocks* one can easily feel when the arteries are near the skin, as at the temples and the wrists : this is what doctors call the *pulse**.

4. Of all that I have been telling you about the **blood**, what I most desire you to keep in mind is this : *there is a* **circulation** ***caused by*** *regular contractions of the* **heart**, and resulting in the forcing of the blood from the heart along the ***arteries*** to the *capillaries*, and from these through the veins back again to the heart.

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1. What is the nature of the coating of the veins? — 2. What is the *nature of the* coating of the arteries? — 3. What results from the rigidity of the arteries? — What name is given to these shocks? — 4. What must be remembered about the circulation of the blood?

This is all we shall have to say on this subject at present.

4. Oxigenation.

251. 1. I have already told you that it is into the **blood**, and by a very curious mechanism, which we will hereafter study, that the nutritive matter passes, after having been reduced to a liquid state. **2.** Once there, the blood carries it off and *distributes the needful share to every part of the whole body;* as *for what remains*, it is destroyed, or rather *consumed, burned up in the blood itself.*

This seems to astonish you. I think I can hear you say, it is really not worth while putting food in the blood merely that it may be destroyed! Besides, how could it be consumed, or burned, there is no fire in the interior of one's body.

Ah! *but there is fire in the body*, my dear children; not a big raging fire certainly, but a gentle fire, producing neither flames nor smoke. **3.** And the proof of this is, that *we have* (*when I say we, I include with us mammalia and birds*), as I have already said and shewn you, *an internal heat* of 39 or 40 degrees centigrade, temperature much higher than that of the surrounding air. In the depth of winter, in the icy regions of the North, when the outer air is at 50° under the freezing point, when the very mercury freezes in the thermometer, *man still retains his* **usual temperature.** You see, then, there must be some *internal fire* that keeps up this heat.

But, you ask me, what can produce this fire? What produces it in the stove, James? — The coals we put in it, Sir. — Of course; but is it the coals alone? Ah! this puzzles you. What do you say, Paul? — Why, Sir, air is necessary; if you close the little opening under the fire place, the fire will soon die out. — Quite right. What then makes the coal thus burn? **4.** Remember your

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1. Where do alimentary matters pass when liquid? — 2. What does the blood do with one part of this? — What becomes of the other part? — 3. What proves that an internal fire is kept up in the body? — 4. What causes the coal to burn in a stove?

lessons on chemistry. — Sir, *it is the oxygen of the air.*—Very well answered. And what is then produced, that escapes by the chimney along with the smoke? **1.** *Carbonic acid gas* and sometimes *carbonic oxide.* — Perfectly so.

Well, children, this is just what goes on in our bodies. **2.** *The aliments there burn, under the influence of the* **oxygen** *of air,* **carbonic acid** *is also produced* there, but never carbonic oxide. Let us look more closely into this; for really the thing is important enough to claim all our attention.

5. Breathing.

252. In the first place, how does the air enter the body? — By the mouth, Sir. — What do you say, Paul? — By the nose, Sir. — You are both right, as regards mankind and some other animals.

3. The real respiratory conduit is the *nose :* the horse, for instance, breathes only by the nose, never by the mouth.

And where does the air thus introduced by the nose or the mouth pass? — Into the chest. — **4.** That is true, but you had better say into the **lungs.**

253. Lungs. — **5.** You all know what **lungs** are like, they are what butchers call *lights.* They are often sold as food for pussy, who is said to be extremely fond of the dainty. I am very sure were these good people to ask pussy's opinion she would much prefer meat; for the lights are a spongy morsel, hard to chew and containing, after all, little besides air.

See, as we have still our dead rabbit, we will just look how the lungs are disposed. The house-wife may not be very well pleased, only science is well worth some sacrifice.

With a pair of large scissors you see I cut away part of the right and left ribs, and thereby the cavity of the chest is laid open. You can see the heart A (fig. 34), and on each side the lungs B and C, soft and flabby.

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1. What is then produced? — 2. Apply these phenomena of combustion *to our bodies.* — 3. Which is the real respiratory conduit? — 4. Where does the air go that we breathe? — 5. What is the vulgar name that is given to lungs?

See here, alongside of the neck this tube D, is strengthened from place to place by gristly rings. **1.** It begins at the back part of the throat, and communicates with the lungs : it is by this conduit that air reaches the lungs; its name is **wind-pipe.** I make therein a little slit, and blow into it through a straw! See how the lungs swell out with the air, which makes them look almost transparent. Whenever I leave off blowing they collapse, and expel nearly all the air they contained.

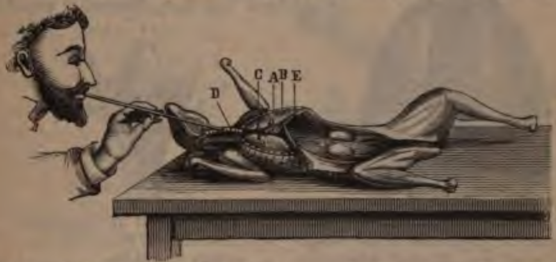

Fig. 34. — I blow into the wind pipe D, immediately the lungs BC swell out, being filled with air.

A, heart. — B, C, lungs. — D, wind pipe. — E, diaphragm.

2. You see, then, lungs are *hollow* organs, whose structure is extremely complicated. **3.** I will cut off a piece presently, and you will see that it very much resembles a sponge, full of air, as I told you a little while ago. **4.** The fact is, that it is formed by a multitude of small tubes called *bronchia*, closed up at their inner ends, and so intricately mingled and wrought into each other that it is almost impossible to follow them out.

254. The larynx. — Such then are the organs into which the air penetrates. **5.** Before proceeding to examine how the air enters, I should like to tell you something about the **larynx** and the **voice. 6.** The larynx, which we can easily feel with our thumb and finger, in front of the neck A (fig. 35), is formed by an enlargement of the wind-pipe, whose two upper

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1. What name is given to the tube that leads from the bottom of the throat to the lungs? — 2. Are the lungs solid or hollow organs? — 3. To what may they be compared? — 4. What name is given to the tubes that form the lungs? — 5. In what is the voice produced? — 6. Where is the larynx situated? — By what is it formed?

rings acquire greater development, and are differently shaped to the others.

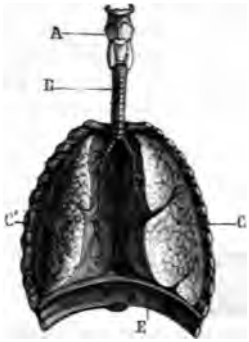

Fig. 35. — Our respiratory apparatus.
A, larynx (apparatus of the voice).
B, wind pipe (through which the air passes).
C, C', lungs, hollow pouches, that receive the air.
E, diaphragm (a thin and flat muscle that separates the chest from the abdomen).

1. Inside there are two tightened folds A, B (fig. 36), called *vocal ligaments* or chords, that become sonorous when forcibly struck by air, thereby producing the sounds of the voice. **2.** These sounds are subsequently modified by their passage through the throat, by the action of the tongue, the cheeks, the lips, and when thus articulated, as people say, they constitute speech.

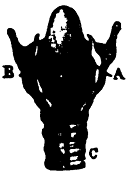

Fig. 36. — Slit up lengthwise in order to show the vocal chords A and B.
C, wind-pipe.

255. Respiratory movements. — Let us now return to the entrance of air into the lungs. How does it penetrate? A little while ago, I blew air through a straw into the rabbit's wind pipe. But very evidently nobody thus acts upon you.

Fig 37. — Respiratory movements. At first there is *inspiration* (the ribs are raised), then *expiration* (the ribs are depressed).

Examine yourselves, each and all of you (fig. 37), by putting one hand on your breast, the other on the *abdomen*. You thereby verify what in fact you already knew, that, regularly, about fifteen times every minute, you take breath, you make *respiratory movements*. And you are also aware

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1. By what are the sounds of the voice produced? — 2. By the action of what organs are these sounds articulated?

that these are double movements; there being first **inspiration**, afterwards **expiration.**

1. During *inspiration*, you feel your ribs raised and your chest widened out, while the abdomen swells as the *air enters* by the nostrils and reaches the lungs. **2.** During *expiration* the contrary takes place, the ribs sink down, the abdomen flattens, the cavity of the chest becomes less, and the *air is expelled*, as from a pair of bellows.

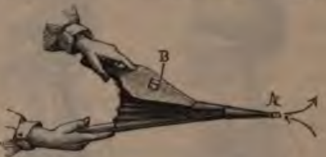

Fig. 38. — The air comes in, and goes out by the tube A, exactly as it enters the chest and leaves by the wind-pipe.

As if from a pair of bellows! This is quite true. Air is drawn into the chest just as into a bellows, it is expelled also as from a bellows. **3.** See here is a pair of bellows (fig. 38) : I close up with a cork the hole B which generally gives entrance to air; then I work the bellows as usual, and the air comes in and goes out by the pipe A, *just as it goes in and comes out of our lungs by our wind-pipe.*

Only in our body, instead of boards, there are ribs joined together by muscles covered over by skin, thus forming a sort of cage called the thorax. Do you see on our rabbit what closes in the cage below (p. 299).

4. It is a sort of thin flat muscle stretched across, separating the thorax, in which the lungs and the heart are situated, from the *abdomen*, which contains the stomach, intestines, pancreas, liver, etc.

5. This muscle is called the **diaphragm.** When at rest, it forms a sort of arch (fig. 34). When it contracts the arch flattens down; of course thus giving greater capacity to the cavity* of the chest : this entails the swelling out of the abdomen, for the diaphragm in descending presses upon the intestine; at the same

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1. What is the action of the ribs during inspiration? — How is the abdomen influenced? — What does the air do? — 2. What happens during expiration? — What becomes of the air? — 3. Explain as compared with the action of a pair of bellows the respiratory movements. — 4. By what is the floor of the thorax closed? — What is contained in the chest? — What is there in the abdomen? — 5. What is the muscle called that separates the thorax from the abdomen?

time the air enters into the lungs by the wind-pipe (fig. 39), just as it enters into the bellows. Simultaneously also, other muscles raise the ribs, enlarging out the chest still more, the sum of all these movements constitutes inspiration.

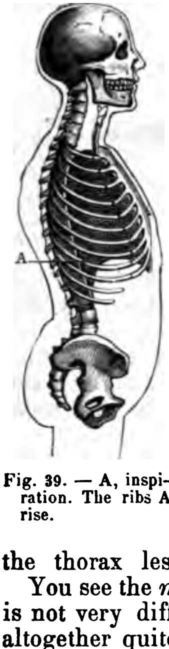

Fig. 39. — A, inspiration. The ribs A rise.

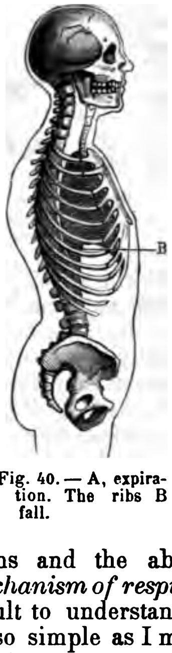

Fig. 40. — A, expiration. The ribs B fall.

Expiration is simpler still (fig. 40). The diaphragm and the muscles that lift up the ribs cease to contract; the lungs, that are very elastic, empty themselves and collapse, as I showed you in those of the rabbit, drawing along with them the ribs that sink down under their traction, and the diaphragm that reassumes its arched position. The air naturally is expelled, at least the greater part, the cavity of the thorax lessens and the abdomen becomes flat.

You see the *mechanism of respiration*, as savants say, is not very difficult to understand. But yet, it is not altogether quite so simple as I make it appear to you.

256. Production of heat. — So you see how the air, and consequently oxygen, manages to enter in to our bodies. But I see you have something to say, Paul.

— Sir, you said a little while ago that the oxygen contained in the air burns the aliments in the blood, just as it burns the coal in the stove. The aliments have entered into the blood, as you told us, but the air, how can it burn them there, since it only circulates in the lungs? My dear child, that was the very thing I was going to explain to you, but I am better pleased to see that the question came from you. This question long remained insufficiently answered, and the real explanation of the problem is quite recent.

I have already told you that blood circulates all through the body. **1**. It must therefore *pass through the lungs, and it circulates at such a rate that all the blood of the body passes in these organs in about half a minute.* **2**. Until lately it was thought that the oxygen of the air consumed the materials of blood *during its passage through the lungs*, and that the furnace that keeps up our heat was situated in that particular place. **3**. But it was clear that if all the heat of the body originated in that spot, the *lungs would inevitably have been* **cooked,** *nay even* **reduced to ashes**. **4**. Subsequently it was ascertained *that when the blood issues forth from the lungs it is cooler than when it enters them*, whilst evidently the contrary would have been the result had the internal fire been in the lungs.

257. Oxigenation and blood corpuscles. — The production of heat takes place in a very curious manner. You remember I told you that there exist in the blood, quantities of tiny red bodies or *corpuscles* to which blood owes *its* rich red colour. **5**. Well, *these corpuscles in passing through the lungs*, **lay hold** *of the* **oxygen** *of air and* **carry it** *along with them.* Thence they penetrate into the utmost recesses of the body, even into the capillary vessels; and in the course of their journey *yield up and transfer to the organs through which they pass a considerable portion of the oxygen they possessed*, for which these organs have greater need and affinity than even the corpuscles themselves.

6. So, *it is* **all through the body** that *the consumption of oxygen takes place*, consequently the *production of heat likewise takes place* **all through the body**.

258. Carbonic acid. — **7**. The consumption of oxygen has inevitably, as you know, for consequence, the formation of *carbonic acid*. **8**. This acid dissolved in

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1. Through what does all the blood of the body pass? — 2. Where was it believed that the combustion of the materials of the blood took place? — 3. What would be the consequences of this? — 4. What observation has been made on the temperature of the blood on leaving the lungs? — 5. In what way do the corpuscles of blood act? — 6. Where does the consumption of oxygen take place? — 7. What gas is produced by the consumption of oxygen? — 8. What becomes of this carbonic gas?

the blood, is carried by it in the course of circulation into the lungs, there it unites with the air and is finally expelled at each expiration.

259. Arterial blood and venous blood. — Thus the blood which the heart propels throughout the body by means of the arteries, is more rich in oxygen than the blood brought back from the organs by the veins.

And, as it is to the oxygen that blood owes its bright red colour, you can easily understand why the arterial blood is redder than the venous blood, which takes a darker purplish tinge.

On the contrary, there is of course more carbonic acid in the venous blood than in that enclosed in the arteries.

260. Expired air. — 1. Thus, as you can easily understand, the *air that has passed through the lungs is by no means pure.* Before entering the body it contained one *fifth* of oxygen, when expelled it only contains about a *sixth,* the difference being made up by carbonic acid. You can easily understand that it must be unhealthy to breathe again the air thus composed; **2.** and it is for this reason that it is necessary to open the windows, or *ventilate** as people say, by some means or other, the rooms in which we live.

3. Were an animal of any kind to be shut up in a tightly closed box, it would certainly perish after having exhausted the oxygen of the air. Death will ensue more or less rapidly, according to the activity of its respiration, which entails a greater or less rapid consumption of oxygen; a frog will live under such conditions longer than a bird; yet of necessity, it also will die. **4.** People say in this case that the creature has been *asphyxiated.* Asphyxia comes on very rapidly under water, because the only air one has at disposal is the little contained in the lungs, and that is quickly exhausted.

We will now leave this difficult and arduous part of our physiological studies, and proceed to that of *sensa-*

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1. What is the nature of the air that leaves our lungs? — 2. Why is it necessary to ventilate the rooms in which we live? — 3. Why must an animal that is kept in a closed box inevitably perish? — 4. What name is given to this kind of death?

tions and *will*, which you will certainly find extremely interesting. But before doing so, if any of you have a question to ask or a remark to make, I shall be more than willing to answer and explain. What have you to say, Paul?

261. Cold blooded animals. — Please, sir, there is something I cannot understand. You have been telling us how heat was produced in living bodies; I can easily understand this in mammalia, and birds that have *warm blood;* but reptiles, fishes, and all the small invertebrates* that have *cold blood*, do they also produce heat?

— **1.** Yes, my child, they do, for as they breathe they must consume oxygen, and produce carbonic acid. **2.** But the production of heat in their case is so extremely insignificant that the temperature of cold-blooded animals rarely exceeds that of the surrounding medium. They are cold when the surrounding element is cold, warm when it is warm. Cold benumbs them so that they are sometimes unable to stir; but they become almost as lively as mammalia or birds under the influence of heat: remember how a lizard becomes brisk and nimble after basking in a warm sunbeam. For the same reason they consume but little food in winter, their organs being but little exhausted by action, for they scarcely breathe; whilst in summer they burn their substance like warm-blooded animals, and eat nearly as much as they do.

In fact, it is not at all easy to give a satisfactory answer to your question. All I can say is that all animals breathe, even those that do not seem to produce heat.

262. Aquatic animals. — Is that all? No? Well, James, what do you wish to say? Please, Sir, animals that live in water, such as fishes and whales, how are they able to breathe?

In the first place, my dear child, you must not class whales with fishes. A whale, as I have already told you, is a mammal, a warm-blooded animal. True it lives in water; but it breathes air, and comes from time to time to the surface for that purpose.

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1. Do cold blooded animals produce heat? — 2. How is it that cold blooded animals rarely exceed the temperature of the surrounding air?

1. As for fishes and other really aquatic animals, what they breathe is air *dissolved* in water. For water contains air, and of this I will forthwith give you proof. I set on the fire a little pan with water in it (fig. 41). **2.** As soon as the water begins to heat, you will see tiny bubbles rise from the bottom of the pan to the surface; observe that the water is as yet far from the boiling point: *these are then bubbles of air*, not of steam.

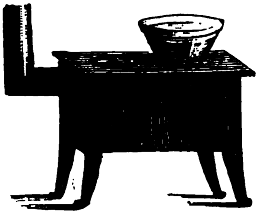

Fig. 41. — As soon as the water begins to heat you see little bubbles mounting to the surface. These consist of *the air dissolved in the water, and not steam.*

3. *This air it is that fishes breathe;* and the proof of this is, that they can live but a short time in water that has been boiled, and from which the air has thus been expelled.

4. They breathe by means of *gills*, or more properly speaking, **branchia** (fig. 42), that is to say, tenuous floating filaments, into which the blood penetrates and where it comes in contact with the air dissolved in the water. Look at this gold fish, **5.** you can see it open its mouth at regular intervals, and at the same time lift up its gills; it thus makes the air dissolved in the water pass over its branchia, just as you in breathing cause the atmospheric air to circulate through your lungs. You see that is very simple indeed.

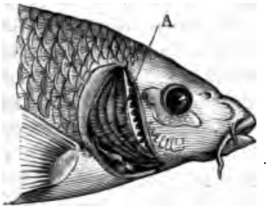

Fig. 42. — A, gills. Fish let the air dissolved in water pass through their *gills*, thus putting it in contact with their blood.

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1. What do fishes do, in order to breathe? — 2. How can you prove that there is dissolved air in water? — 3. Why does a fish die quickly when placed in water that has been boiled? — 4. In fish what takes the place of lungs? — 5. Why does a fish regularly open its mouth, and then its gills?

SUMMARY. — NUTRITION.

1. In **nutrition**, there are two functions to be considered: 1. **digestion**, which has for aim to *dissolve* the aliments, so that they may traverse the intestines and enter into the blood. 2. the **absorption** effected by the blood.

2. **Digestion** (p. 289). — The **digestion** takes place in the digestive tube, with the help of the *teeth* and under the action of the *digestive juices*.

3. **Teeth** (p. 289). — The *mastication* or action of chewing the aliments is accomplished by the *teeth*, and aided by the *tongue*.

4. A full-grown man has 32 teeth, 16 in each jaw : 4 *incisors*, 2 *canines*, and 10 *molars*. — Until about the age of seven, children have only 20 teeth: the difference bears upon the molars.

5. Teeth are composed of *ivory*, overlaid with *enamel*. They are fixed in the *jaws* in holes, called alveoli, by one or several roots. In each tooth there is a cavity which serves as a receptacle for *nerves* and *blood-vessels*.

6. **Saliva** (p. 290). — The grinding of the aliments is facilitated by the outflow of *saliva*, a liquid formed by the *salivary glands;* tears are formed by the *lachrymal glands*, and sweat by the *sudoriparous glands*.

7. **Alimentary canal** (p. 291). — The aliments pass down through the chest in a tube called *œsophagus*, and reach the *stomach*.

8. From there, the alimentary matter passes into the *small intestine*, and finally into the *large intestine*.

9. This system of tubes is called the *alimentary canal*.

10. **Digestive fluids** (p. 292). — The aliments are not only passed through the alimentary canal, but there they are also **transformed**, under the influence of *juices* or fluids supplied by different glands.

11. The first of these juices is the *saliva* which transforms flour into *sugar*.

12. The *gastric juice* secreted by the stomach dissolves flesh, albumen, and in general all animal substances.

13. The aliments which have escaped the influence of the saliva, and the gastric juice, are dissolved by the glands of the small intestine, of which the most considerable is the *pancreas*.

14. The *liver*, another very important gland situated to the right of our body, is the organ in which *bile* is produced. The blood is purified in passing through the liver by giving off those substances which constitute the bile.

15. **Absorption** (p. 293). — The aliments rendered liquid, pass through the tissues of the intestine and mingle with the blood. The blood then carries them all through the body : this is what is called **absorption**.

16. Blood (p. 294). — Blood is a *yellowish* liquid, in which float an extraordinary number of very little *red* corpuscles.

17. Circulation (p. 295). — The blood is sent all through the body by means of a hollow muscular organ called *heart*, which contracts regularly: each *contraction* or « throb » sends out into the arteries a gush of blood.

18. The blood is conveyed to the heart by soft tubes called *veins*, and it leaves by others much more rigid, called *arteries*.

19. All the arteries *divide* and subdivide, finally forming minute *capillaries;* these *reunite* to form larger and larger vessels called veins. It is in all these that the blood flows or is said to *circulate*.

20. Thus the blood passes from the heart to the arteries, from the arteries to the capillary vessels, from the capillary vessels to the veins, and from these back to the heart, and all this is accomplished by the impulse imparted by the heart after each contraction. This is what is called the **circulation.**

21. The *pulse*, which one can easily feel at the wrist or at the temple, is produced by the shock of the blood in the arteries, which, at these places, are quite near the skin.

22. Oxigenation (p. 297). — The blood carries off the dissolved alimentary matters, and deposits a certain part of them all through the body; the rest is *consumed* in the blood itself.

23. This combustion maintains in our body a temperature of 39 to 40°.

24. The factor necessary for this combustion is found in the *oxygen* contained in the air we breathe; it produces the *carbonic acid gas* which is cast out.

25. Breathing (p. 298). — The air we breathe passes through a tube called *trachea* (windpipe) and penetrates into the **lungs.**

26. The lungs are hollow organs; they are formed by a number of tubes called *bronchia.*

27. About 15 times every minute, the chest which is closed below by the *diaphragm*, expands, thus inhaling the *surrounding* air: this is the act of *inspiration.* Subsequently the chest lessens in capacity, so that the air is expelled; this is the act of *expiration.*

28. By means of what is called the circulation of the blood, all the blood of the body *passes through the lungs* in half a minute; the corpuscles of the blood lay hold of the oxygen of the air at each inspiration and carry it along with them to the utmost recesses of the capillary vessels. In the course of this journey they give up a great part of this oxygen to the organs they permeate.

29. In this manner it is that the oxygen is consumed all over the body and not only in the lungs, therefore heat is produced likewise all through the body.

30. An animal deprived of air perishes, *asphyxiated.*

31. The air which our lungs reject is not pure, for it contains carbonic acid; therefore it is necessary to ventilate, or renew the air in our dwellings.

32. Cold-blooded animals also consume oxygen, since they breathe; but the production of heat which ensues is so very scanty that the temperature of their bodies rarely exceeds that of the surrounding medium.

33. Fishes breathe, by means of their *gills*, the oxygen that exists dissolved in the water.

[Simple *Subjects for composition* are to be found at page 323.]

III — SENSATION.

263. You remember the simple experiment in which we so frightened the poor chickens by suddenly opening the window. What enabled them to hear the noise of the window? Their ears, was it not? And by what were they enabled to perceive the presence of Paul, that so terrified them? With their eyes of course. And with what were they able to flee from the danger? With the muscles of their limbs. And with what were they able to understand that they were menaced, and to command the movement that was to carry them to a place of safety? Ah! you are unable to answer this time. Well, I will tell you, it was with their **brain**.

But the brain is in the cavity of the skull, the eye is in its socket, the ear is in a hollow of the skull, the muscles of the limbs are far removed in the under part of the creature. What can put the *eye* and the *ear* in connection with the *brain*, and the *brain* with the *muscles?*

264. Nerves. — 1. *Communication is established by what physiologists call* **nerves**. **2.** These nerves are excessively fine white threads, that pervade all the parts of the body. **3.** Some carry to the brain *the sensations that come from* **without**, and their ramifications are so numerous that it is impossible to prick any part of your skin with the finest needle without injuring one of them and without feeling a sensation of pain; **3.** others convey from the brain *orders of* **motion**, and carry them to the muscles of the whole body.

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1. By what intermediary do the eye, ear and muscles communicate with the brain? — 2. What are these nerves? — 3. There are two categories of nerves, to which do they belong?

1. The former are called **sensory** *nerves*, and the latter **motor nerves.**

265. Spinal cord. — The nerves do not land directly in the brain. **2.** All those that exist in the body and in the limbs communicate in the first place with the **spinal cord** (fig. 43). **3.** This spinal cord or marrow is, as its name indicates, a sort of cord, externally of a whitish colour and greyish internally; it is situated in the canal of the vertebral or spinal column, which canal is on that account often called *medullary canal* (from the Latin *medulla*, marrow).

4. Between each *vertebral interval* there shoot forth, to the right and to the left, nerves B, each of which goes to some allotted part of the body.

At C, in the lumbar region, the marrow tapers off to an end. **5.** In the superior regions at F, it passes into the skull, swells out and becomes what is called the **medulla oblongata.**

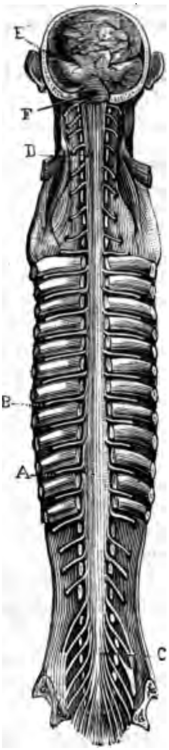

Fig. 43. — A, the medullary canal.
B, a nerve, passing out between two vertebræ, to be distributed to the adjacent parts.
D, C, spinal cord, from which the nerves of the body and members take their birth. It is enclosed in the spinal canal.
E, brain.
F, medulla oblongata, from which the nerves of the face and head arise, as well as those that preside over the movements of the heart and respiration.

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1. What name is given to nerves of the first category? — To those of the second? — **2.** Where do all the *nerves that exist in the body and limbs start from?* — **3.** Where is the spinal cord placed? — **4.** Between what parts of the vertebral column do the nerves pass out? — **5.** What name is given to the spinal cord, at the place where it enters the skull?

1. *The nerves of the face and of the head arise from this medulla oblongata, and also those that preside over the movements of the heart and of the lungs.* This allows you to understand the extreme gravity of a wound in this medulla oblongata, and why a fatal issue is always inevitable, and that in a very short space of time. **2.** For it checks both the **circulation of the blood** and the **respiratory movements.** Into this medulla oblongata cooks sometimes drive a long pin when they wish to kill their poultry instantaneously, and this is what is wounded and even severed by dislocation when they strike the fatal blow close behind the ears of a rabbit.

266. The brain. — **3.** Almost the whole cavity of the skull is filled by the **brain.** It is a large pulpy mass, grey without, white within, and which in mankind and in many of the mammalia is all covered over with sorts of folds called *convolutions.*

4. *It is in the brain that* **intelligence** *resides,* that **sensations** are perceived and **ideas** *formed,* and *there also that* **will** *originates.* The more intelligence an *animal* has, the more brain it possesses. In mankind, when the weight of the brain is less than 2 pounds, the man who is so scantily provided is an idiot. **5.** If the brain be wounded, intelligence is weakened, and the sufferer becomes mad, or insane: this happens also after certain diseases. In some cases such wounds however may heal, and the intelligence partially, if not totally, recover.

If the brain be destroyed, no trace of intelligence will remain. **6.** Such a thing has come under notice in the case of some birds whose brain alone was wounded, the medulla oblongata being uninjured. Being carefully nursed, their life was spared, but both *intelligence* and *will* had completely disappeared. *The brain gone,* the bird will remain on its perch without ever having the idea of moving, or seeking food. Nay it would die of hunger beside heaps of food without

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1. What are the nerves that take their origin in the medulla oblongata? — 2. Why is a wound in the medulla oblongata mortal? — 3. By what is the cavity of the skull filled? — 4. Of what faculty is the brain the seat? — 5. What happens when the brain is wounded? — 6. What happens when the brains of certain animals are removed?

ever thinking of eating; but if its food be put into its beak, it will unconsciously swallow it and digest it as if nothing had happened. If flung into the air, it quite unconsciously spreads out its wings and flies right before it, until it meets with some obstacle or drops down exhausted. Birds in this condition have been known to be kept alive for months, their guardians having nursed them by putting food into their throats; during all the time they continued to live in this condition, they never gave the slightest sign of intelligence or will. Let us now pass on to sensations.

267. Tactile* sensation. — Firstly we may mention the *general sensation of* **touch**, which lets us know that some object is in contact with our body. **1.** All the surface of the skin is affected by this, also the lining of the mouth, that of the nose, the eye, the ear, etc. **2.** Everywhere, over all this surface, ramifications of the *sensory nerves* are spread, which when excited transmit the sensations they receive to the *spinal cord*, and thence to the *brain*, just as an electric wire carries a telegram.

3. When these nerves warn us that something has touched us, they tell us at the same time if it is something *colder or warmer* than *our body* with which we have come in contact, and also approximately the proportion of cold or heat: we have thus the *sensation* of **temperature.**

Both these sensations, that of temperature and that of contact, are generally included under, and expressed by the general name of **feeling** or **touch.**

Feeling can really be said to exist only when **our intelligence enters into action**, in order to make use of the sensitive powers of our skin. **4.** Generally it is with the **hand** we touch or feel things. This five-armed compass which *man alone possesses*, is a most marvellous instrument, not only with which to grasp powerfully or handle delicately, but also to give a pretty accurate idea of the body it touches. See here is an apple.

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1. On what parts of our body does the sensation of touch take place? — *2. To what is* the sensibility of our *skin due?* — 3. What other sensation is given us by the nerves that reach our skin? — 4. With what do we generally exercise the sense of touch?

I lay my fore-arm on it (fig. 44). You will easily believe that were I blindfolded, it would cost me a good deal of time and observation to ascertain, by means of feeling with the skin of my fore-arm alone, that I have to deal

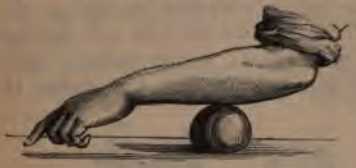

Fig. 44. — With the fore-arm, it requires time to perceive that an apple is a round, polished, and resisting body.

Fig. 45. — It suffices, to take it for an instant in my hand, to perceive all that.

with a rather hard, roundish, and polished body. Whilst, I should find out all those facts in an instant were I to take the apple in my hand (fig. 45), because I would bring a great many points of its surface in contact with my skin.

268. Gustatory[*] sensation. — 1. The mouth is capable of exercising a sort of feeling called **taste.** **2.** The substances we put into our mouth, if capable of melting or dissolving, produce particular impressions, known by the name of *savours*. Every body knows about them, and we often hear about things that have sweet, or salt, or bitter savours. Some people spend their lifetime in efforts to satisfy this one sense of taste. The culinary art has been invented in order to satisfy it within reasonable limits; and that very properly too, for experience has proved that generally speaking food which is agreeable to the palate is easily digested.

269. Sensations at distance. — But setting aside the very limited notions which the sense of *taste* furnishes to us, you see that *touch* tells the shape of bodies, their hardness, their polish, their temperature and several other properties.

This is undoubtedly a great deal; but had we only that, we should be rather poorly informed. **3.** Fortunately even at a distance we can detect the presence of

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1. Name a certain variety of touch, the seat of which is in the mouth. — **2.** What name is given to the impressions furnished by the taste? — **3.** Name the sense which at a *distance* informs us of the presence of other bodies.

objects, by **smell**, by **hearing**, and especially by **sight**, which last alone might almost supply the place of all the others.

270. Olfactory sensation. — **1.** The *olfactory* organ is the *nose*, or more properly speaking the *nasal chambers*. **2.** These are two cavities AB (fig. 46) separated by a vertical partition C, which cavities open in front by the nostril and behind into the throat D, opposite the opening of the larynx E. The air breathed during respiration under ordinary circumstances passes by this channel. There are even some animals, as I have already told you, that breathe exclusively through the nose; and were the nostrils of a horse to be closed, that animal would very rapidly die from asphyxia, or privation of air.

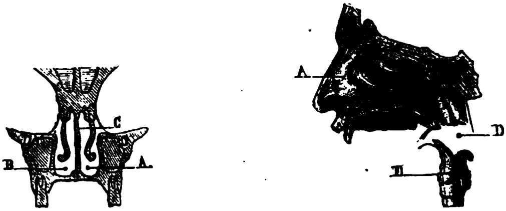

Fig. 46.

Section of the nose, seen from the front. Section of the nose, seen from the side.

A, B, nasal chambers. D, back of throat.
C, vertical partition. E, opening of the larynx.

Smell, at each inspiration makes us aware of the proximity of certain bodies which, for reasons as yet unknown, have the faculty of making impression upon our olfactory organ, and are as people say, *odoriferous*. Unfortunately, as we have already seen in former lessons, some very noxious gases have no smell whatever, so that we may be poisoned by inhaling them unawares.

271. Auditory sensation. — **3.** *Hearing* informs us, as you know, of the existence of *vibrations* termed *sonorous*. It teaches us moreover to measure and appreciate them, for with practice, and when one is particularly gifted, it is possible to distinguish exceed-

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1. What is the organ of smell? — *2. What do you* call the *chambers of the nose*? — **3.** What does hearing teach us?

ingly slight variations in sounds. We have already seen in physics, that our ear could not detect a sound unless the number of vibrations exceeded 32 per second. This is the *very lowest sound* that can be heard by us; the *highest* is produced by 76000 vibrations per second.

Vibrations coming from without can be transmitted to the **auditory* nerve** in two different ways; when we have to deal with the vibrations of a solid body we perceive them by simply laying the body close to our skull.

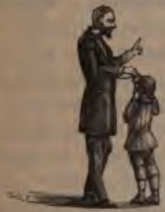

Fig. 47. — Stop your two ears. I place my watch on your forehead, you clearly hear the tic tac.

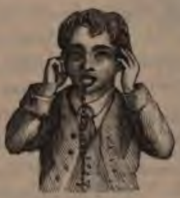

Fig. 48. — Take the watch between your teeth you still distinctly hear it.

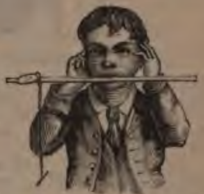

Fig. 49. — I place my watch on a flat ruler : you still hear it.

Come here, Paul, and stop up your ears closely with both hands (fig. 47). I will put my watch against your forehead, and you will hear quite distinctly its tic-tac. Open your mouth now, and take my watch between your teeth (fig. 48), you will still hear it very well. Now take this flat ruler between your teeth (fig. 49); I lay my watch upon it, and the result is the same.

In this last experiment the sonorous vibrations, produced by the works of the watch, have set in motion successively the watch case, the ruler, the teeth, the skull bones, the liquid of the ear, the terminations of the auditory nerve, and thence have reached the brain.

But direct transmission such as this is very rare. In the great majority of cases, sound is produced by the vibrations of a body separated from us by *air*. In this case it is the vibrations communicated by the air to our ear that must be detected and heard. This causes considerable complications of the auditory organ.

272. 1. The component parts of the ear are, firstly

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1. What name is given to the exterior part of the ear ?

the *pinna* A (fig. 50). This external part is very much developed in animals of acute hearing, which turn and direct it so as to catch the greatest possible quantity of sound. The horse (fig. 51) for instance pricks up his ears, turning them towards the direction whence comes the sound! — Our *pinna* is of but little importance and almost motionless; it is of some use however, and we turn it to catch the sound, only the whole head turns along with it, — when the sound is not sufficiently strong, sometimes we even place our hand around the ear behind the pinna, thus making a sort of ear trumpet.

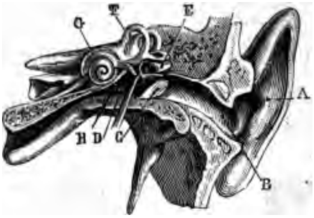

Fig. 50. — Auditory apparatus.

A, pinna.
B, auditory passage.
C, membrane of the tympanum.
D, cavity full of liquid.
E, chain of small bones.
F, semicircular canals.
G, cochlea in connection with the auditory nerve.
H, membrane of the cavity full of liquid.

1. By the pinna, vibrations are gathered together and introduced into a passage B, called the *auditory tube* or *meatus*. In mankind it is but a few inches in length.

2. At its base C, the vibrations come in contact with a sort of thin skin, stretched across the auditory passage, which it closes up: this skin is the *membrane of the tympanum*. This membrane is also set in vibration in its turn.

Fig. 51. — The horse directs his ear toward the point of origin of the sound.

Here we come to a very curious and interesting part of the auditory function. There is an interval of about an inch between the membrane of the tympanum and the cavity D full of liquid, which has next to be set in

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1. What name is given to the tube *which is continuous* with the pinna? — 2. *What* do the vibrations meet with at the bottom of the auditory tube? What name is given to this membrane?

motion. This bony cavity has an opening closed up by a second outstretched membrane.

1. Now between this last-mentioned membrane and that of the tympanum there exists a chain of tiny bones or ossicles E, the ends of which chain are in contact with the two membranes. This arrangement allows the vibration of the membrane of the tympanum to be transmitted to that of the cavity, thence to the liquid, and lastly to the auditory nerve G.

2. In short, if we recapitulate we shall find that the sound takes the following course, first air, membrane of the tympanum, ossicles, membrane of the cavity, fluid of the cavity, nerve! Thus the vibrations have passed successively through gases, solids, liquids. You see what a complicated thing hearing is, and yet I have omitted a great many very interesting details.

273. Visual sensation. — Now let us consider the eye, the organ of *visual sensation.* It is a most delicate organ, but its mechanism is more easily understood than that of the ear, and I shall be able to show you all the principal parts of this important organ with the help of this ox eye the butcher gave me (fig. 52).

You can observe that it bears no little resemblance to an egg, the shell of which, although pretty hard, is not calcified. **3**. At the tip of this shell, you find this white string : it is the **optic nerve**, the nerve destined to convey to the brain the impressions made upon the eye by light; it penetrates as you see into the eye, and now we will follow it and ascertain what becomes of it.

4. The outer coat of the eye G is opaque* excepting in the front part A, where it becomes transparent so as to allow the light to enter.

5. This transparent part is called **cornea**.

6. The light passes through this cornea A; but before reaching the back part of the eye, and after having run through a little chamber B full of liquid, it falls upon a sort of curtain C called the **iris**, which is stretched out and has in the centre an opening D called the **pupil.**

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1. What is there between the tympanum and the internal cavity full of liquid, that has to be put in motion? — **2.** Indicate what course the vibrations must take. — **3.** Where does the optic nerve terminate? — **4.** Is the entire globe of the eye opaque? — **5.** What name is given to the transparent part? — **6.** What does the light meet with after having traversed the cornea?

Come here near the window, Henry; and all of you stand around him and be attentive. Henry's eyes are blue (fig. 53), that is to say, that the little curtain, the *iris*, is of blue colour. In the centre of the iris D you see a small round hole, quite black. **1.** That is the *pupil;* through it the light passes into the eye.

Now wait a little; I will close Henry's eyelid for a short time, then suddenly open it again. Did you observe what took place? The little black hole was *very large* (fig. 53) immediately after I lifted the eyelid, only as soon as the light reached it (fig. 54), it became small (fig. 54). Now you see it is quite small, almost a speck; let us now go to the further end of the school room where the light is less strong, see the pupil enlarges again. What does this mean? Oh, you will all easily follow the explanation. **2.** When there is *but little light, the pupil widens out* so as to gather in as much as possible: when on the contrary *the light is strong, it draws itself* in, allowing only the necessary quantity to pass through, thus keeping the optic nerve from being fatigued or *dazzled.*

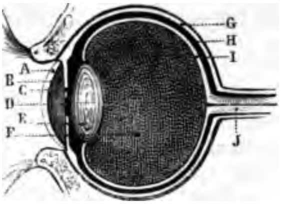

Fig. 52. — The eye, organ of vision. Section of the eye of an ox.

A, transparent cornea.
B, anterior chamber full of liquid (aqueous humour).
C, iris.
D, pupil.
E, crystalline.
F, sticky liquid (vitreous humour).
G, globe of the eye (sclerotic).
H, choroid.
I, retina.
J, optic nerve.

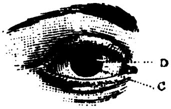

Fig. 53. — C, Iris. — D, pupil, large in a dim light.

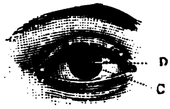

Fig. 54. — C, iris. — D, pupil, small in a bright light.

There, we have seen how the light gets into the eye; now we must follow it and see how it goes on. For this

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1. What name is given to the *little hole which* is in the iris? — *Where does the* light enter the eye? — **2.** Why is the pupil large when there is only a little light? and why is it small in a strong light?

purpose the bull's eye (fig. 52) will be most useful. Here it is cut open lengthwise. **1**. See the globe of the eye is filled F with a sort of sticky but very transparent liquid. You can easily recognise the cornea A, and the curtain C of the iris. **2**. And now just behind the pupil D, look at this pretty hard, transparent body E, shaped exactly like a magnifying glass: it is the **crystalline lens.**

All over the back part of the interior of the eye is spread a sort of greyish membrane I, very easily torn. **3**. This is the **retina**; it is formed by the termination of the optic nerve in the eye. **4**. It is this retina which receives impressions from the light, and it is on it that the images of surrounding objects are formed.

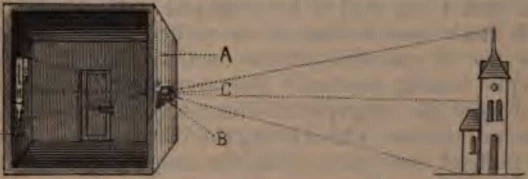

Fig. 55. — Dark room.

The shutter A is the iris. | The lens C is the crystalline.
The hole B of the shutter is the pupil. | The sheet of paper D is the retina.

How can this take place? Ah! if you have kept in mind the experiment we made in the *dark chamber* you will have no difficulty in understanding it. We will however repeat it once more. Let us go into our *dark room* (fig. 55). Here is a small hole B through which passes a ray of light. I place my lens C over this, and on the opposite wall D, I place a sheet of paper. After some focussing, we can manage to arrange things so that the image of the neighbouring church is to be seen on the paper. You are aware of that!

5. Well, the shutter A plays the part of the *iris;* the hole B in the shutter, that of the *pupil;* the lens C, of the *crystalline lens;* the sheet of paper D, that of the *retina*. Such is, reduced to its most elementary expression, the phenomenon of vision.

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1. With what is the globe of the eye filled? — 2. What is found just behind the pupil? — 3. What is the retina which lines the back of the eye? — 4. In what way is the retina acted on? — 5. Compare the different parts of a dark room with the different parts of an eye.

274. Short-sighted and long-sighted persons. — In the course of our experiment you might have observed that it was only when I placed my sheet of paper at a certain distance from the shutter, that a distinct *image was obtained;* the paper was then, as I have already explained to you, in focus. When it was too near or too far off the reflected image was dim and ill defined.

1. Now, it sometimes happens that a person's eye is a little too shallow, sometimes a little too deep. When it is too shallow, the image falls *behind* the retina, and persons whose eyes have this defect are said to be *myopic*, or *short-sighted;* when on the contrary the eye is too deep, the image falls *before* the retina, and persons having this defect are said to be *presbytic* or *long-sighted.*

2. Both these defects in the sight can be obviated by the use of spectacles, those destined for short-sighted people having *concave** glasses that draw backwards as it were the image, whilst long-sighted people require *convex** glasses, which bring the image farther forward. In both of these cases then, the image is produced distinctly upon the retina.

The sense of sight is the most precious of all. It acquaints us with the shape, the dimensions of bodies, and lets us know at what distance they are. It also gives us notions of colours.

275. False sensations. — All this is undoubtedly very marvellous and admirable. Yet notwithstanding, the eye is by no means a perfect instrument. Nay it would often lead us into error, did we not rectify* by our reason the false impressions it sometimes gives us. In some cases even, we cannot altogether correct them. I will give you an example.

You have not forgotten the colours of the *spectrum:* violet, indigo, blue, green, yellow, orange, red. Let us single out the green, for example. Well the same green may be obtained, that is the same sensation of green, in examining the green of the spectrum alone, or combining in due proportion blue and yellow. Like-

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1. What name is given to persons *who can only* see objects when placed *near the eye?* And to those who *only see well* at a distance? — 2. With what kind of spectacles are near-sighted persons relieved? And long-sighted?

wise, we can artificially obtain a violet colour in mixing together red and blue, and orange with red and yellow. The eye is in this case completely deceived, and deceives us at the same time, as it does not enable us to detect the slightest difference between a *simple* and a *compound* colour.

276. Reasoning. — Were we in possession of sight alone, we should fall into many more errors. But hearing, and especially touch, help us to rectify our mistakes. Upon the whole, all these divers sensations sending information to our brain, enable us to form a pretty accurate idea of all that is going on around us. Thereupon *our brain reasons*, and induces us to make use of all that is good for us, to avoid what would harm us, and so to act as to improve even nature by countless inventions and industries. A dog's senses are as keen as ours; that of smell is in his case infinitely more acute; and yet he cannot make use of all his powers for improving his situation or making progress, *because he is not endowed with sufficient intelligence.* Some people say, the cause of his inferiority is lack of hands and speech. But had he ten hands he could not utilise them as we do. And if he does not speak, it is because he is incapable of inventing words. Poor idiots have hands, and often they cannot speak. *But it is neither the hand nor the tongue that makes man what he is, it is his intelligence and his brain.*

SUMMARY. — SENSATION.

1. Nerves (p. 309). — **Nerves** are kinds of delicate white threads that pervade the whole body.

2. Some carry to the brain sensations that come from without: those are *sensory nerves.*

3. Others convey orders for motion from the brain to the muscles throughout the whole body: those are *motor nerves.*

4. Spinal marrow (p. 310). — **The spinal marrow** or **spinal cord** is a sort of white cord hidden in the canal that runs through the vertebral column, which canal is formed by superposed rings.

5. At the spot where the spinal cord penetrates the skull, it widens and becomes what is called the **medulla oblongata.**

6. The nerves of the body originate in the spinal marrow; those of the head, together with those that rule over the movements of the *heart* and those of *respiration*, arise from the medulla oblongata.

Injuries to the medulla oblongata are inevitably mortal.

7. **The brain** (p. 311). — The cavity of the skull is almost entirely occupied by the **brain.**

8. It is in the brain that *intelligence* resides, there it is that *sensations* and *ideas* are formed, there also that *will* originates.

9. Injuries to the brain, if not fatal, entail a weakening of intellectual power.

10. A bird may live although deprived of its brain, if all its wants are carefully supplied; it will inevitably die if any harm reach its medulla oblongata.

11. **Tactile sensations** (p. 312). — The general sensation of *touch* warns us when some object has come in contact with our body.

12. This sensation can be transmitted by any part of the body, but more particularly by the hand.

13. Tactile impressions are transmitted to the spinal marrow, thence to the brain by the *sensory nerves*, whose termination ramify beneath the surface of our skin :

14. These nerves also impart to us the knowledge of the *temperature* of bodies.

15. In the mouth there exists the peculiar sort of *touch* called *taste*, which gives us impressions of *savours.*

16. **Sensations that give impressions at a distance** (p. 313). — Tactile sensations inform us only of objects we touch; *smell*, *hearing*, and especially *sight*, tell us of what is at a certain distance from our body.

17. The *organ of smell* is the *nose*, or more precisely speaking the *chambers of the nose*, that open into the throat opposite the entry of the larynx.

18. *Hearing* acquaints us with what are called *sonorous* vibrations.

19. **The ear** (p. 314). — The vibrations received by the *pinna* of the ear travel along the *auditory tube* at the extremity of which they come in contact with the *membrane of the tympanum* which they set in motion. The vibrations of the membrane of the tympanum are transmitted by a chain of *little ossicles* to a *second membrane*, which closes up a cavity full of liquid. This liquid in its turn transmits the vibrations to the *auditory nerve*, which carries them to the *brain.*

20. **The eye** (p. 318). — The *eye* is a sort of globe, transparent only in its front part, called the *cornea.* Behind the cornea is a sort of curtain called *iris*, which is sometimes grey, sometimes blue or brown, giving to the eye its peculiar tint. This curtain is pierced with a central opening, called the *pupil*, through which light enters into the eye, after having passed through a sort of magnifying lens called the *crystalline lens*, placed just behind the pupil. The light then passes through the transparent fluid which fills the globe of the eye and falls upon the *optic nerve*, which under the name of *retina* overspreads the inward surface of the back part of the eye.

21. **Reasoning** (p. 321). — Had we only our eyes and the other organs of senses to direct us we should be led into error in many cases. Our brain surveys all however, being called into action by our sensiferous organs: it reasons and teaches us to take advantage of things that are useful, and to avoid those that would do us harm.

22. It is neither the hand nor the tongue that makes man what he is : it is his intelligence, and his brain.

SUBJECTS FOR COMPOSITION.

1st **composition** (p. 274). — Composition and structure of bone. — Of what use is the marrow of the bones?

2nd **composition** (p. 275). — What a vertebra is. — The different regions of the vertebral column. — The appendages of the vertebræ of the dorsal region. — The manner in which the ribs are united in front. — The five vertebræ united constitute the sacrum. — Which is the bone that is supported by the sacrum?

3rd **composition** (p. 277). — By what is the skull supported? — The interior of the skull and its communication with the vertebral canal. — The cavities of the skull. — The two jaws.

4th **composition** (p. 278). — The bones of the upper or fore limbs and of the hand. Which bone articulates with the humerus? — With which bone does the scapula or shoulder blade articulate? with which the clavicle or collar bone?

5th **composition** (p. 279). — The bones of the lower limbs. — Upon which bone does the *femur* articulate? — To which bone is the pelvis attached?

6th **composition** (p. 280). — Describe an articulation. What insures the solidity of an articulation? — When is a joint said to be sprained? — when dislocated?

7th **composition** (p. 281). — Of what use are muscles? — In what manner are the muscles frequently fastened to the bones? — Muscular contractility. — Muscles of the fore-arm.

8th **composition** (p. 283). — Show how it is that we should not be able to stand erect were it not for the help of the muscles.

9th **composition** (p. 286). — Voluntary movements, involuntary movements.

10th **composition** (p. 289). — The teeth, their names and their number. — The different parts of a tooth.

11th **composition** (p. 291). — The course the aliments take in passing through the alimentary canal.

12th **composition** (p. 293). — Part played by the saliva, — by the gastric juice, by the intestinal juices, by the pancreatic juice. — The liver. — The aim of digestion.

13th **composition** (p. 293). — Part played by the blood. — By what organ it is impelled through the blood vessels. — Arteries. Veins. Capillary vessels. — Circulation.

14th composition (p. 297). — Into what do the aliments pass after the digestion has liquified them? — What becomes of them? — Why is our temperature almost invariably at about 39° centigrade?

15th **composition** (p. 300). — How does the air penetrate into our body? — The lungs. — Respiratory movements.

16th composition (p. 303). — By what process is the oxygen of air consumed in our body. — Production of carbonic acid.

17th composition (p. 305). — How do fishes breathe?

18th composition (p. 311). — The brain. — Spinal marrow. — Medulla oblongata. — What happens to birds in which brain has been destroyed?

19th composition (p. 312). — Touch. — Taste. — Sensations produced at a distance.

20th composition (p. 314). — The nose.

21st composition (p. 316). — The ear.

22nd composition (p. 318). — The eye.

VII—VEGETABLE PHYSIOLOGY.

277. Vital acts are similar throughout all the animal kingdom. — We know how animals live, how and why they eat and breathe, how they move about, how they feel, and how they manifest will. I say "animals" although I have scarcely spoken of any excepting the vertebrates, scarcely even of mankind, because in reality it is essentially the same phenomena we meet with in all. When a cockchafer flies, it sets its wings in motion by contracting its muscles, just as we do when we set in motion our arms, etc. True, the cockchafer has no bones affording to its muscles a point of support, but its hardened skin answers the same purpose. When a snail withdraws its horns on being touched, it is because it feels the contact of your finger by the mediation of a nerve, just as we might do. When a butterfly that you try to catch, looks at you and flies away to escape from you, it reasons in its little brain just as the chickens did when Paul frightened them. An animal may have four feet or six, or two or even none at all, it may feed on grass or on flesh, it may live hidden in a hole, or under the deep water, or soar in the open air above the clouds, the great question with it ever is, to eat enough to replenish what its organism has used, to feel, to move, to will; it is always a matter of stomach, muscles, nerves and brain.

We must now try and see *how* **plants** *live*. At first sight this study seems less interesting than that of animal life, because plants have no power of locomotion, neither have they feeling nor will; consequently · no muscles, nerves, brain, nor sense organs. But they require food, they grow, and in this respect they afford, as I will hereafter show you, a still more curious study than even animals.

We will begin by what is most astonishing in our subject, namely the *development*.

278. Germination. — Once more we will consider the haricot bean (fig. 1) which has already been so useful in our botanical lessons; I will once more show you the parts that compose this seed; so we will in the first place take off the skin, which for us has no great importance. This discloses to you two fleshy* masses A, B, the *cotyledons;* between those you see the young plant C with its radicle or rootlet, its tiny plumule above.

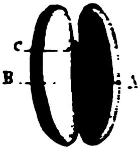

Fig. 1.
A, B, cotyledon.
C, young plant.

Here is another haricot (fig. 2). This time the radicle projects about an inch above the cotyledons D, E; the stem B also has stretched out, and begins to unfold tiny leaves C. This haricot has begun to **shoot.**

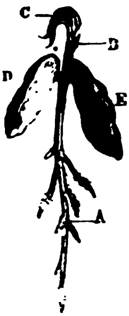

Fig. 2. — A haricot that has germinated, thanks in the first place to moisture, in the second to heat, and in the third to the oxygen of the air.
A, radicle.
B, stem.
C, young leaves.
D, E, cotyledons.

279. Conditions necessary for germination. — You wish to know how this result was obtained. Some days ago I put the haricot into a pot amongst some damp pounded bricks. The moisture swelled up the skin of the bean, soaked the young plant, which drought had kept asleep as it were, and thus awoke it.

So the plant grew.

1. **Moisture** *then is an indispensable condition of* **germination.**

2. So when one desires to keep seeds for any length of time, they must be carefully housed in some *dry place*, otherwise they begin to shoot: that is a fact every one knows.

You must not conclude however that moisture alone suffices to induce germination. If we were in winter, and if my haricot, even moistened, had been submitted to the temperature of *two* or *three degrees centigrade* above the freezing point, it would not have begun to

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1. What condition is necessary to germination? — 2. What precaution must be taken when we wish to prevent seeds germinating?

shoot; at *ten degrees centigrade* the germination would have been but very slow. We are in summer, the thermometer* of the schoolroom indicates 20 degrees centigrade; therefore the germination has gone on rapidly. **1.** Besides moisture then, a *certain degree of* **heat** *is also necessary in order to allow seeds to germinate;* and the greater the heat, the more rapidly do they shoot up, this in a moderate measure of course : it would be quite a mistake to have them cooked, if you desire them to grow.

This is not all. *The haricot* I show you, *began to shoot because it was* **in air.** Had I put it under water it would not have done so, even had it not lacked heat. **2.** It requires then air also. **3.** And as you can easily imagine, *what it requires from air is* **oxygen.** It can perfectly do without nitrogen, but it greedily *absorbs* the oxygen, it *breathes* it, and gives back just as an animal would, *carbonic acid.*

See here is a glass bottle, closely corked (fig. 3), into which I put some barley seeds moistened so that they might shoot. They have grown a little as you see, then died *because all the oxygen that was in the bottle was exhausted.* See here is the proof of what I say. I set fire to this bit of straw and plunge it into the bottle : the flame goes out immediately because there is no oxygen. If I had the proper apparatus here, I could show you that what has taken its place is simply carbonic acid.

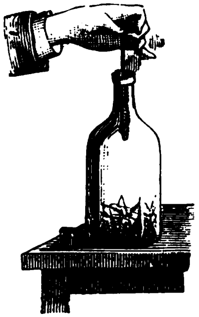

Fig. 3. — The flame goes out immediately because the oxygen of the flask has been absorbed by the seed that has germinated.

4. So, *the seed in the course of* **germination** *consumes oxygen and yields up carbonic acid ; its respiration is similar to that of an animal.*

But carbonic acid is produced by combustion* of

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1. Does moisture alone suffice for germination? — What more is wanted? — 2. What else is wanted to nduce our haricot to sprout? — 3. Does it take from the air oxygen or nitrogen? — 4. In short, what does a plant do in germination?

carbon in oxygen. Where does the seed find the **carbon** it thus burns?

280. Consumption of carbon during germination. — Observe the cotyledons of this haricot, they are quite flaccid, shrivelled and half empty, instead of being round and fleshy as before. **1.** *It is they that have furnished the carbon.* They contained starchy matters, which are rich in carbon, these have almost completely disappeared to such an extent that the haricot has become quite unfit for eating.

281. Vegetation in the dark and vegetation in the light. — This source of carbon can last for a long time. See here is a haricot (fig. 4), that I planted about a fortnight ago, at the same time as another I will soon show you. I planted it in pounded, moistened brick, only instead of leaving it exposed to the light I kept it in the *dark*. **2.** It has grown quite yellow, as you see, it is as we say *etiolated*. See, its stalk is about 20 inches long. **3.** And had I dried the entire plant, leaves, stem, and what remains of the

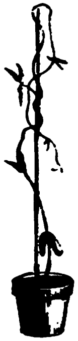

Fig. 4. — A haricot that has germinated in the *dark*, it is yellow, and has lost its weight, having lived only on the carbon of the two cotyledons.

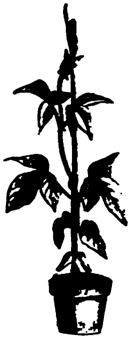

Fig. 5. — A haricot that has germinated in the *open air*, it is green, its weight has increased; it has lived on the carbon that it took from the carbonic acid of the air.

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1. What has furnished the young plant with the carbon which has been *burned in* the oxygen of the air?— *2. What happens* to a haricot that *grows in the* dark? — 3. What has been observed in the weight of a haricot that has germinated in the dark, compared with the weight of one that has not germinated at all?

haricot itself, you would see that the whole *weighs much less* than a mere haricot bean, dried in the same fashion before having grown at all. The cotyledons are in fact quite dried up and exhausted.

And now let us pass on to another phenomenon. Here is the haricot (fig. 5) I spoke about a few minutes ago, planted at the same time as the former, under similar conditions. **1.** Only this one has grown in *full sun light*; its stem is green, its leaves are broad and healthy.

2. Were we to dry it, it would weigh *much more* than a simple haricot, similarly dried.

The shoot of the first haricot, that grew in the dark, is *yellow*, and the whole plant, haricot, stem and leaves *has decreased in weight*; on the contrary, the shoot of the second that grew up in the light, is *green*, and its *weight has increased.*

282. Light causes increase of weight. — *So light makes the plant grow* **green,** *and causes* **increase in weight.** But where has the plant found material wherewith to augment its weight in *solid matter?* I, of course, leave aside the water it drinks. Has it found it in the soil or in the air?

The experiment was made in such a way as to exclude all possibility of the plant taking any substance from the soil. The flower-pot in which it was planted contained only pounded brick; it might have contained pounded china or glass, the result would have been the same. The plant certainly found no nourishment whatever in the flower-pot; it could moreover be very easily proved that the weight of the brick dust has not at all diminished.

3. Then of course the additional substance found in the plant must have been derived from the air?

Yes, it was! But what has the plant taken from the air? Ah! this is something most marvellous, and that long remained a mystery. **4.** The *plant, in order to vegetate**, *absorbs* **carbonic acid,** *which is always to be found in the air; decomposes it,* **retains** and *utilises the* **carbon** and **gives back the oxygen.** I will

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1. What happens to a haricot that grows in the open air? — 2. What may be observed on weighing it? — 3. Where has the plant found what was necessary to augment its weight in dry material? — 4. What has it taken from the air?

forthwith relate to you an experiment that proves this statement.

283. Absorption of the carbonic acid of air. — In the course of the last century, an English chemist named Priestly*, had placed two mice under a glass shade; naturally, after a certain length of time they both died of asphyxia, having used up all the oxygen of the air under the shade, and of course emitted carbonic acid. Priestly then conceived the idea, for what reason I cannot tell, of putting under the same shade, into the very air which had proved fatal to the poor mice, a small plant with healthy green leaves. Strange to say, *the plant* not only *did not die*, but even appeared to prosper; this result was certainly very interesting, but the most astonishing part of the story is yet to come. Some days afterwards, Priestly removed the plant and put another mouse in its stead. Now this one lived where the others had died; it only died in the ordinary lapse of time, that is to say after having consumed all the oxygen; then of course it was asphyxiated like the others. This proves that the plant had *purified*, rendered *respirable*, the air that had been tainted and made impure by animals.

Great was Priestly's astonishment, and no wonder! So much the greater was it, in those days when but little was known of the composition of air, or of what carbonic acid, or oxygen was. All this must have appeared at that time obscure enough.

At the present day it is quite plain, thanks to chemistry. It is known, as I told you, *that plants absorb carbonic acid, decompose it in order to live upon the carbon, which they retain, whilst they reject the oxygen.* We are thus enabled to explain Priestly's experiment with perfect ease and precision. The mice had consumed all the oxygen of the air under the shade, they moreover tainted it with carbonic acid, the product of their respiratory oxidation: an animal could no longer live therein. The plant *absorbed the carbonic acid*, *retained the carbon*, and *restored the oxygen;* so that the air became once more fit for breathing.

284. Action of light on the green parts of plants. — Upon close examination it was seen that two conditions were requisite before the plant could accomplish this process.

1. 1st **That the plant be green**, for the green parts alone are capable of thus decomposing carbonic acid; 2nd *That the plant should be exposed to* **sunshine** or at least to **sunlight.** Under these conditions the rapidity of the decomposition coincides with the intensity of light; it ceases completely in darkness.

285. Experiment. — I undertook to prove to you all I have just advanced, so we will now proceed to make a simple experiment. Here is a large vessel of clear white glass (fig. 6). I filled it at the fountain, and brought it here a few hours ago, so that the water might not be too cold. Paul, go to the old water cask at the bottom of the garden and bring me some of those long green filaments that grow on its edges, and which I may tell you are called *confervæ*. That is right. See I hang them on the edge of the vessel, allowing them to float in the water.

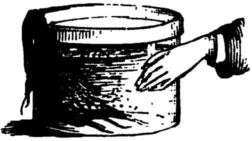

Fig. 6. — Under the influence of light the green *confervæ* have decomposed the carbonic acid of the water, taken up the carbon and set at liberty the oxygen.

We are in the shade here; let us transport our precious dish in *full sunshine* and wait a little. See now how many little bubbles of gas appear on the green wavy threads? If we shake the vessel gently they will get loose and rise to the surface. *This gas is pure oxygen, which the green plant, under the influence of light, has formed, by decomposing the carbonic acid that exists in the water;* for it is to be found in water as well as in air.

Now, we will carefully shake the confervæ, so as to detach all the bubbles, then we will cover the glass vessel with this thick box so as to put the whole thing in complete darkness. When school-time is over we will lift it off again, and *we shall see that no new bubbles of oxygen will have been formed, because the plant will have remained in the dark.*

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1. What conditions are necessary to enable a plant to decompose the carbonic acid of the air, and to restore the oxygen?

Had I had time to go to the river side to fetch you an aquatic plant called *Potamogeton*, you would have seen the same phenomenon, but with much greater intensity. Under the influence of light, this plant discharges oxygen with such rapidity that with a funnel I should have been able to gather a sufficient quantity of it to fill a tube (fig. 7), with which we might have relighted a match as we did in our chemistry lesson. We may do so at some future day.

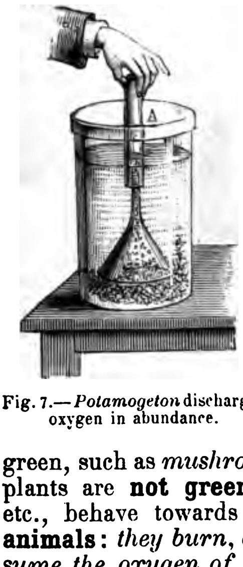

Fig. 7.—*Potamogeton* discharges oxygen in abundance.

Thus *two conditions are necessary for the purification of air* by plant life, **green substance** and **light.**

286. Parts of plants that are not green. — But, you may inquire : what happens to the plants that are not green, and what happens when there is no light, during the night for instance, to plants that are green?

1. That can be easily explained. Plants that are not green, such as *mushrooms*, or the parts that in ordinary plants are **not green**, viz : the *flowers*, *fruit*, *roots*, etc., behave towards the air, **exactly the same as animals**: *they burn*, *or if you like it better*, *they consume the oxygen of air and they fabricate carbonic acid*, and that whether they be in light or in darkness.

2. As for the **green** parts *they remain inactive during darkness*.

287. Recapitulation. — After all I have been telling you I should like some one to prove that he has properly understood me. Could you do so, Paul? How does a green plant act in the day time? — Sir, it purifies the air, it *takes in the carbon of carbonic acid and rejects the oxygen.* — Well; can you tell me what particular parts of the plant are at work in this operation?

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1. What, as regards the air, is the behaviour of plants that are not *green, such* as mushrooms, or of the parts that are not green in ordinary plants? — **2.** What do the green parts do during the night?

— Its green leaves, and the green parts generally. — Quite so; now the roots and bulk of the stem, how are they engaged whilst the green parts work so? — I think they act as animals do : *they inhale the oxygen* and *exhale carbonic acid*. — That's quite right.

Thus, simultaneously, in the same plant, two opposite phenomena take place : the production of carbonic acid by the parts that are not green, and consumption of carbonic acid by those that are green. Only, the latter activity being very much more powerful than the former, the plant, not only does not augment the proportion of carbonic acid in the air, but consumes what it finds there.

288. The real nature of the absorption of carbonic acid. — The expression « respiration of plants » as you will find it written in many books, is then quite erroneous when applied to the decomposition of carbonic acid of the air. True those parts of the plants that are not green breathe like animals, but the decomposition of the carbonic acid by the green parts *is quite the reverse of respiration*, and bears a much closer resemblance to **digestion**.

The word digestion applied to plants seems to afford you some amusement, master Paul, why so, pray? — Because, Sir, plants have no stomachs. — If that is your only reason, my child, it has but little value : for there are members of the animal kingdom, whose organisation is so very rudimentary that they are not even provided with a digestive canal, yet they are able to digest the suitable aliments that come in contact with their bodies; all the surface of their body thus acting as digestive organs. But tell me, why do people digest? — In order to nourish the body. — Well then, when the plant decomposes carbonic acid, don't you think it *nourishes itself upon the carbon* it retains for its own use? If you consider the composition of the plant, you will find that carbon forms about the half of its substance. **1**. Well, this carbon it obtains from the carbonic acid of the air that surrounds it, from the water which bathes its roots and which it sucks up into its body. *You see the word*

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1. Why is the absorption of carbonic acid by the green parts of plants a digestive process?

digestion was quite applicable, and comes nearer the truth than that of respiration.

And this is why the haricot I showed you a little while ago, that had breakfasted on sunlight, had prospered and grown heavier. It is for this reason and after this manner, that all green plants around us grow (fig. 8). All day long they are busy decomposing carbonic acid, in order to lay in provision of carbon, so as to be able to add to their stature and their weight. Through the dark hours of night they take rest, they even use up a little of their store of carbon laid by in the day time, and thus they exhale carbonic acid. You see all this is very simple indeed.

Fig. 8.—The green parts decompose the carbonic acid of the air, retain the carbon, and give up the oxygen.

289. Winter. — I see James has a question to ask? — Please, Sir, in winter when the leaves have fallen off, what happens? — That is a very good question, my dear child. Well, in winter things go on in the same way as during the night. **1.** The plant breathes, and consumes day and night the carbon it had gathered in during its green time, in the long summer days. **2.** So at the end of winter the plant weighs less (in dry material of course) than at the beginning. *They have lived on their store.* If winter were to last for ever they would all perish of hunger.

Has any body any thing else to ask? — Please, Sir, of what use are the roots, since it is the leaves that nourish the plant? Why are they watered, why are they manured? — Oh! oh! these are a good many questions at once. But be patient, they will all be answerd.

290. Part played by roots. — Of what use are roots? **3.** In the first place they support the plant, for it would be unable to stand against the wind were it

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1. What happens in winter when the leaves have fallen? — **2.** Give me a proof of it. — **3.** What is the use of roots?

not for their aid. You can easily understand this, so I need insist no further on the subject.

Why do we water plants? Let us try to reason a little. A plant is like a sponge full of water. In the air, in sunshine, if cut down, it gets rapidly dried up. **1**. It would dry up in like manner standing; but its roots plunge down into a soil more or less moist, and suck up into the body of the plant the necessary supply of water. Hence when the soil is dry it requires to be watered.

2. Things go on in the following manner: the leaves that the sun threatens to dry up, suck water from the branch on which they grow; the branch draws up its share from the stem; the stem from the root, which in its turn renews provision from the soil.

3. The moisture is as it were sucked by the evaporation of the leaves; it rises, through the wood, circulating in very fine tubes or vessels.

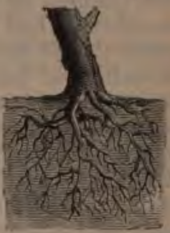

Fig. 9. — The roots transmit to the plant water and all the matters that can be drawn from the soil.

Thus you see plants should not be watered at random. It is necessary to consider the degree of heat, the state of the air, or of the wind, the area of the plant exposed to evaporation, and also its mode of living, for whilst some plants require great quantities of water, others want but little. These last have generally thick fleshy leaves that enable them to have a certain quantity of water in reserve, or they are provided with roots that penetrate deep into the soil and reach places that are always damp.

291. Absorption in the soil of nutritive matter. — **4**. The water that the roots thus obtain from the soil is not pure distilled water; it has dissolved all that could be dissolved in the earth through which it has filtered, and the roots absorb these substances along with the water they suck up.

5. This is most important, for vegetable matter contains not only carbon, hydrogen, and oxygen (the constituents

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1. What other services do roots render to plants? — 2. Describe what takes place. — 3. Show how the water rises from the roots to all parts of the tree. — 4. Is pure water drawn up by the roots? — 5. What else is there in vegetable matter beside water and carbon?

of water) and water, but also *nitrogen*, although in lesser quantity than in the bodies of animals. It also contains *phosphorus*, *potash*, *lime*, *salts*, *silica*, *iron*, etc.

1. All this they find in the water, which their leaves inhale and their roots* absorb.

292. Necessity of manure*. — You can easily believe that by dint of dissolving the different substances of which I have been speaking, water at length impoverishes the soil, so that the necessary aliments of the plant are no more to be found therein. In nature things go on quite smoothly all alone. When a plant has grown, and when by its roots it has absorbed all the nourishment its soil could afford, it *dies*, falls, rots on the place it had exhausted, and *returns to the ground what it had taken from it.* But when a plant grows in cultivated land, things are altogether different, we cut down the plant and *carry it away;* thus it happens with cereals*, with fodder, we cut them for use instead of allowing them to fall down and die like wild plants. And the poor earth, who will repay it for all it has given to the corn, to the hay? Naturally it becomes exhausted; and, after two or three crops of corn, has nothing more to give to feed corn, which refuses to grow there; *what has been taken away must then be given back*, in some shape or other.

This is why *manure* is indispensable. **2**. All plants have need of nitrogen; so farm-yard manure, which contains a great deal of it, does well with all of them. But it is a very remarkable fact, that all plants do not absorb exactly similar substances; naturally, it is necessary to give back to the soil precisely the substance the plant has consumed in it. **3**. Thus the vine contains not a little potash; therefore wood ash is excellent manure for vineyards, because it is rich in potash. **4**. Wheat contains phosphorus; hence phosphates, crushed bones, will greatly facilitate its vegetation. All this is plain enough and easy to understand as a principle.

But I must add something further. I said a minute

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1. By what agency is all this furnished them? — 2. Why does farm-manure suit all plants? — 3. How ought the vine to be nourished? — 4. What is the nourishment that suits wheat?

ago : « When a plant has grown, it dies, rots on the place it occupied, and gives back to the earth what it took from it. » This is quite true, but it is not the whole truth. The plant yields to the earth not only what it took from it, but also what it took from the air, that is to say, all its carbon, its nitrogen also, which is extracted from the soil by a very curious and intricate process; you can thus understand how it is that *exhausted land left to rest*, as people used to say, becomes fertile again, by the sole action of weeds that spring up upon it. The land is as it were manured by nature. Only, practically speaking, it is generally more lucrative to put dung on the land so as to enable it to be continuously yielding produce.

293. Plants fabricate what animals consume.—You now have a pretty accurate idea as to how plants live, and you can understand why their existence is indispensable to animals. **1**. It is plants which, by the action of light on their green substance, take in carbon from the air, by means of their roots take the hydrogen and oxygen from water they find in the soil, nitrogen from the nitrogenous mineral compounds, and with all these *fabricate the organic matter which is necessary for the life of animals*, such as the starchy matter, sugar, oil, and the nitrogenous constituent of the corn (gluten). **2**. *The animal by itself cannot fabricate anything; it is only capable of constantly transforming*, of consuming, and restoring to the state of water, carbonic acid, nitrogenous mineral compounds and the organic matter which the plant had produced precisely with these very elements.

3. Thus the animal eats the plant (herbivorous), or else it eats the animal that has already fed on plants (carnivorous); be this as it may, the animal lives on the plant.

4. Again when the animal dies, the plant finds aliment in its dead body; and even during the life of the beast, the plant feeds on the carbonic acid rejected in animal respiration as well as by the waste products of its alimentation. **5**. Thus the animal feeds on the plant and

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1. What do plants do with all they absorb? — 2. Can an animal fabricate anything? — 3. On what does an animal live? — 4. What services does the animal render the plant? — 5. To what may these mutual services be compared?

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the plant on the animal, with the help of sunshine and air.

294. Sun indispensable to life. — The first indispensable requisite to life is the **sun**. 1. Were the sun to be extinguished, the green parts of the plant could no longer fulfil their functions; they would even disappear, as is the case when a plant grows in darkness. Hence no formation of new vegetable matter, and subsequent death of animals whose store of food would soon be exhausted. So it may be truly said that all life depends on the sun, for were its heat or its light to fail, nothing living could exist on the face of the earth.

295. Subjects of study necessarily left aside. — I have now told you all that the limits of this course of lessons will admit upon vegetable physiology. Many more very interesting branches still remain to be studied. You have yet to learn about the substances formed by green leaves; how the sugar contained in the leaves, — in the stem of the vine or in wheat, for instance, quits these organs and goes to form the sugar of the grape, the starchy matter of the grain of

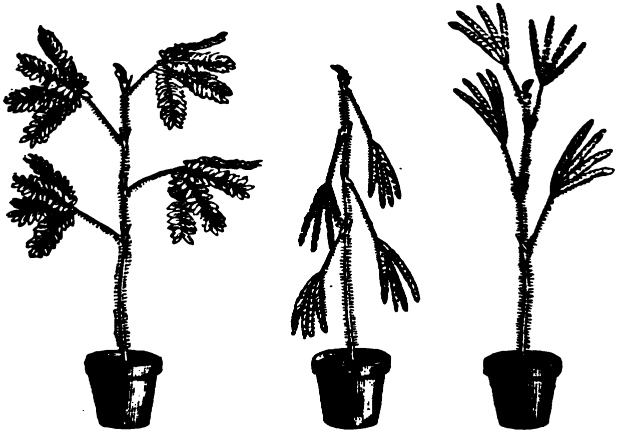

Fig. 10. — Sensitive plant intact, after a shock, sleeping at midnight.

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1. *What would become of plants and life generally if the sun were extinguished?*

wheat; how it is that beet stores up in its root, during the first part of its existence, the sugar it will require during the second, when it will bear flowers and seeds; how the different juices circulate through plants, and what the *sap* really is; all about the *bud*, and how it can live when separated from the plant that bore it, and can be transplanted by *grafting* or by *slips;* how the pollen and the ovule come in contact with each other, contact necessary for the formation of the seed; how some plants have one aspect in the day time and another after night fall, either as regards their leaves, as with the acacia, or their flowers, as with the field daisy; how some plants *sleep;* how others have parts that seem to have feeling, and move when touched as the sensitive plant (fig. 10), or the stamina of certain flowers.

You see much remains to be learned. But the great thing is to understand perfectly how plants fabricate organic matter, and I hope you all know that now.

SUMMARY. — VEGETABLE PHYSIOLOGY.

1. **Germination** (p. 326). — **Moisture** is indispensable to germination.

2. A certain degre of **heat** is likewise necessary.

3. It is also indispensable that the seed have access to **the air.**

4. The part of the air necessary for the growth of the plant is **oxygen.** This the plant absorbs, breathes, burns and gives back *carbonic acid* just as an animal would do.

5. To be thus able to burn or consume oxygen, *carbon* is necessary; this the young plant finds in its cotyledons.

6. If the seed germinates in the dark, the germination will take place exclusively at the expense of the carbon contained in the cotyledons; the plant will grow up yellow, and, if weighed after desiccation will be found to be lighter than a mere haricot bean similarly desiccated without having sprouted.

7. Thus in the dark the plant springs up yellow, and its weight diminishes.

8. If on the contrary the plant is grown in daylight its shoot will be green; when desiccated it will be found to weigh more than a haricot bean desiccated without having germinated.

9. When the plant has exhausted the carbon contained in its cotyledons, or even before it is quite exhausted, it will absorb the carbonic acid contained in the air, and decompose it, retaining the carbon and giving back the oxygen.

10. **The action of light on the green parts of plants**

(p. 328). — Plants purify the air: only in order to accomplish this purification the two following conditions are indispensable : 1. The plant must be *green*, as the green parts alone decompose carbonic acid; 2. the plant must be exposed to sunlight.

11. In the dark, the decomposition of carbonic acid ceases completely.

12. **Parts of Plants that are not green** (p. 332). — The parts of plants that are not green, such as the flowers, fruits, roots, act, as regard the air, just as animals do, *they consume oxygen and exhale carbonic acid.*

13. **Digestion of plants** (p. 333). — Thus, those parts of the plants that are not clad in green, *breathe* like animals; but the decomposition of carbonic acid by the green parts is rather a *digestive* than a respiratory act.

14. The plant feeds on the *carbon* it retains, just as animals feed on the carbon they find in their aliments.

15. In winter, when the plants have lost their leaves, and consequently have no green parts, they live on the store of carbon laid in during the summer.

16. **Part played by the roots** (p. 334). — The roots, in the first place, sustain the plant, and keep it from being overturned; but this is not the only part they play.

17. The water of the soil, sucked up to replace the water evaporated by the leaves, contains several substances: nitrates, phosphorous, potash, lime, silica, iron. These substances are absorbed by the plant.

18. **Use of manure** (p. 336). — After a certain length of time, however, all these substances are exhausted by the plants; it is in order to replenish the earth with them that manure is necessary.

19. **Plants fabricate what animals consume** (p. 337). — It is the plants which with the help of their green substance and light, extract from the air its carbon, from the soil the hydrogen and oxygen of water, nitrogen from the nitrogenous mineral compounds, and that with all these substances, fabricate the organic matter necessary for animal life : starchy matter, sugar, oil, gluten.

20. An animal is incapable of fabricating any thing; it can but restore to the state of water, carbonic acid, or nitrogenous mineral compounds, the organic matter which the plant had produced with precisely these elements.

21. Indispensable to all this is *sunlight.*

SUBJECTS FOR COMPOSITION.

1st composition (p. 327). — How does a plant obtain its carbon during the process of germination? — Difference between a haricot that has sprung up and grown in the dark, and a haricot that has sprung and grown in the light. How does a plant breathe during the process of vegetation?

2nd **composition** (p. 330). — Experiment of Priestly proving the absorption by green plants of the carbonic acid of air. Experiments of like description with *confervæ*, etc.

3rd **composition** (p. 330). — The action of the green parts of plants. — How do these green parts act during night? — How do the leafless trees live throughout winter?

4th **composition** (p. 333). — Why are we entitled to say that the absorption by plants of the carbonic acid of air is a digestion rather than a respiration?

5th **composition** (p. 334 and 336). — The function of roots. — Necessity of manure.

DICTIONARY

Aërial, that lives in air.

Aggressive, that attacks without having been provoked.

Air-pump, pump by which air may be exhausted from any vessel.

Algeria, French colony in the north of Africa.

Alps, chain of mountains that separate France from Switzerland and Italy.

Alpine, of the Alps.

Altitude, height of a place above the level of the sea.

Amphibia, animals that live sometimes in water, sometimes in air.

Anatomist, one who studies the organism of the body, be it the human body or that of any animal.

Annuals, that live only one year.

Annulates, animals whose bodies are composed of a series of ring-shaped divisions.

Aquatic, that lives in water.

Arable (soil), land that can be cultivated. Arable soil is a mixture of calcareous powder, grains of flint, clay dust and animal and vegetable remains.

Artificial, produced by art, or man's industry. The contrary of what has been produced directly by nature.

Asia-Minor, name given by the ancients to that part of Asia that lies to the south of the Black Sea and which is also called Turkey-in-Asia.

Australia, an island of Oceania, about the size of Europe. Belongs to England. The principal towns are Melbourne and Sydney.

Baltic, a sea in the north of Europe. It lies between Russia and Sweden, and to the north of Germany.

Beds (of rivers), the hollow or canal in which the river runs.

Beds (of gardens), plots of ground specially disposed for careful culture.

Beer, the produce, by fermentation, of steeped barley or hops.

Biennals, that live during only two years.

Bomb, hollow ball of metal, filled with powder and fired from a short cannon called a mortar. The bomb explodes by means of a match.

Borneo, an island of Oceania; belongs partly to Holland.

Botanist, one who studies plants. Botany the study, the description and classification of plants.

Bow (fiddle), the instrument used to sound a fiddle or violin.

Brass, an alloy of copper and tin.

Burrow, to hollow out.

Calcine, to reduce to powder by heat. Calcination, the act of reducing to powder by heat.

Carapace, a sort of shell which protects and encloses the bodies of tortoises and some reptiles, etc.

Carnivorous, animals that feed upon flesh.

Cavity, a hollow.

Century, a period of a hundred years.

Cereals, collective name given to some plants of the grass family, wheat, barley, oats, whose seeds, ground into flour, are food to mankind.

Chio, an island in the Mediterranean situated to the south-west of Asia-Minor. Chio was partly destroyed in 1881 by an earthquake.

Colony, properly, a group of persons settled down in a foreign country. Applied in natural history to animals that live in groups.

Combustion, decomposition of a body by the action of heat.

Compressed, pressed together so as to occupy less space.

Concave, hollow and arched as the inner surface of a round body. A concave lens is a piece of glass slightly hollow on both sides.

Conical, shaped like a cone. A sugar loaf is conical.

Convex, a convex lens is a piece of glass slightly swelling out on both sides towards the centre.

Cuvier, celebrated French naturalist

(1769-1832). The creator of paleontology, the science that treats of beings that have disappeared

Denmark, a country in the north of Europe.

Deviate, to turn aside from the straight line.

Diameter, straight line passing through the centre of a circle and terminated at both ends by the circumference.

Dikes, banks; mounds formed to prevent inundations.

Distil, to evaporate and subsequently condense a liquid.

Domesticate, to make familiar; to tame wild animals so as to render service to mankind.

Effervescence, a sort of boiling up caused by the escape of gas under different conditions.

Elasticity, the property of returning to a previous form, the cause of the alteration being withdrawn.

Emission, the act of emitting; that is, giving out, throwing forth.

Expand, to enlarge in bulk; to spread out.

Fermentation, decomposition which takes place under the combined influence of warmth, air and moisture; the elements of the substances acted on afterwards reuniting into a new combination.

Fifth (music), a musical interval of five notes following each other, the two utmost being comprised.

Fleshy, when well furnished with flesh. Is used in speech about fruit as well as about real flesh. Pears, peaches, etc. are said to be fleshy.

Fontainebleau, a town in the centre of France.

Friable, easily reduced to powder. Calcinated substances are friable.

Fructify, fructification, to bear fruit, the act of bearing fruit.

Gaboon, country on the west coast of Africa.

Gallery, a passage or corridor. Often applied to passages in mines.

Germination, the act of sprouting. A seed that germinates is a seed that begins to shoot forth, to grow.

Glass (magnifying), instrument used in order to make things appear larger and allow people to study minute objects.

Greenland, Danish possession in the north of the American continent, a great extent covered with icefields.

Guinea, country on the west coast of Africa.

Gum-arabic, a vegetable juice, that oozes out of some trees and becomes solid by contact with air.

Gustatory, that is in relation with the sense of taste.

Hemispheres, half-spheres. A sphere is a round globe-shaped body. People speak of the terrestrial hemispheres, the world being considered as a globe divided into two equal parts.

Herbivorous, animals that feed upon plants alone. Grazing animals.

Hibernating state, state of animals that *sleep throughout* winter.

Horizontal, *parallel* line with the *horizon. The surface* of still water is *horizontal.*

Hot-house, a glazed house artificially heated and disposed for growing plants that require more than ordinary heat.

Immemorial, beyond memory. So far back, so ancient, that no memory, no recollection has remained.

Internal, inward: interior; what is not outward or external.

Invertebrates, animals that have no vertebral column, or bones properly so called.

Keel, the lowest timber of a ship, extending from end to end all along the bottom of the vessel.

Kneaded, wrought and pressed into a uniform mass. Bread is kneaded.

Larvæ, insects in their « masked » or first state of existence.

Larynx, upper part of the wind-pipe, called also the throat, and which contributes to the formation of the voice.

Limestone, calcareous stone much used for building.

Linnæus, celebrated Swedish naturalist, (1707-1778), author of the classification of plants.

Liquified, rendered liquid.

Loadstone, an ore of iron which has the power of attracting iron. It is also called natural magnet.

Luminous, that gives light.

Madagascar, large island on the eastern coast of Africa, capital Tamatave.

Mammalia, animals that feed their offspring with milk, (from *mamma* the Latin for breast).

Manure, substance added to the soil to increase its fertility.

Marine, concerning the sea. Something that lives in, or close to, the sea. **Marine** animals, marine plants.

Martinique, one of the West India islands.

Masticate, to chew. **Mastication**, the act of chewing.

Membrane, an organic film. A sort of outspread skin.

Mercury, a metal, called also quicksilver. The only metal which remains liquid at the ordinary temperature.

Microscope, an optical instrument of much more complicated construction than the magnifying glass and of greater magnifying power.

Milan, a town in Italy, in the valley of the Po.

Mine, a pit or excavation in the earth, from which ores or other minerals such as coals, etc are obtained by digging.

Molar, a double tooth or grinder.

Molluscans, animals whose bodies are soft and pulpy.

Mortal, capable of causing death.

Moulded, what has been shaped or fashioned in a mould. The mould is an object hollowed out so as to give a certain shape to that which is run or kneaded into it.

Movable, that can be moved.

Naples, one of the principal cities of Italy.

Naturalist, one who studies, or is versed in natural history.

Newfourdland, great island of the Atlantic to the north-east of North America. An English possession.

New-Zealand, English possession in Oceania. Principal towns Auckland, Dunedin, Wellington. The principal exportations are gold and wool.

Nocturnal. of the night; nocturnal bird : bird that flies abroad only during the night.

Octave, a musical interval of eight consecutive notes.

Oil, name given to all greasy substance which preserve their liquid state at an ordinary temperature.

Opaque, not transparent. That cannot be seen through.

Perennial. a perennial plant is one that remains in life for several years.

Physiologist, one who studies the science that treats of the phenomena of life: of the functions of the organs in animals or plants.

Pilfering, stealing.

Poland an ancient European state, at the present day divided between Russia, Prussia and Austria. The name of Poland is given to the part annexed to Russia.

Prey, spoil; that which is, or may be seized by violence, to be devoured.

Priestly, a learned chemist and experimentalist who lived in England (1733-1804). The French Convention awarded him the title of French citizen.

Protuberance, something that swells or bulges out.

Pulse, the throbs caused by the motion of the blood in the arteries. Those throbs are easily felt at the wrist or the temples, because in these places the arteries lie very near the skin.

Putrefaction, rottenness. Decomposition that takes place in all dead organic bodies.

Pyrenees, chain of mountains that separate France from Spain.

Quadrupeds, four-footed animals.

Reef, a chain of rocks lying at or under the surface of the sea.

Reptiles, cold-blooded, aërial vertebrates, whose bodies are covered over with false scales. Tortoises, serpents and lizards are reptiles.

Rhone, a river which rises in Switzerland, runs through the lake of Geneva, and continuing its course through France falls into the Mediterranean sea.

Scale (musical), a series of harmonic sounds in their natural order.

Siberia, country in the north of Asia.

Slip, a twig taken from a parent plant and destined to be planted, to take root and so furnish a new plant.

Spindle, a small instrument used for spinning. Is a sort of piece of wood rounded like the bar of a chair, swelling out towards the middle and tapering off at either end.

Spitzbergen, group of islands of the Arctic ocean, to the north of Lapland.

Starch, substance extracted from many plants, particularly from wheat. Starch mixed up with water is used to stiffen and dress linen.

Structure, mode of composition of a body; how its different parts are disposed in relation to one another.

Subjugated, conquered; made subject to.

Submerged, entirely covered by water.

Sucker, an apparatus that acts upon the same principle as the small disc of steeped leather with which schoolboys lift up stones. Some animals use these apparatus in order to lay hold of their prey, or to adhere to anything.

Tamed, reduced from a wild to a domestic or mild state.

Thermometer, instrument used to ascertain the degree of heat of any body or that of the surrounding air. This is obtained by means of the contraction and expansion of mercury or alcohol.

Tinder, substance given by a sort of mushroom, which is made to undergo a chemical process which renders it very easily kindled.

Tinned, lined or overlaid with a coating of metal. Mirrors are lined with a mixture of tin and mercury.

Transverse, crosswise.

Triangular, that has the form of a triangle : three cornered.

Trunk, the prolongation of the elephant's snout.

Twilight, doubtful light; the faint light between sunset and night, or between sunrise and day.

Valley, a space of ground low lying between two or more hills or mountains.

Vegetation, development, growth of the parts that constituate the plant.

Ventilate, to renew the air : to make a fresh supply of air pass through a room, etc.

Vertical, perpendicular, that follows the direction of the plumb line.

Vertebrates, animals provided with vertebræ The vertebra is one of the small bones which compose the vertebral or spinal column.

Volta, a celebrated Italian who studied natural philosophy and invented many instruments for his experimentation. The most celebrated is the electric pile, which still bears his name.

Wieliezka, a town in Poland.

Wine, alcoholic liquor obtained by the fermentation of the juice of grapes.

Zoophytes, animals that have a plant-like appearance, such as coral.

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